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AIR&SPACE

Smithsonian•August/September 1993

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August/September 1993
Volume 8, Number 3

AIR&SPACE
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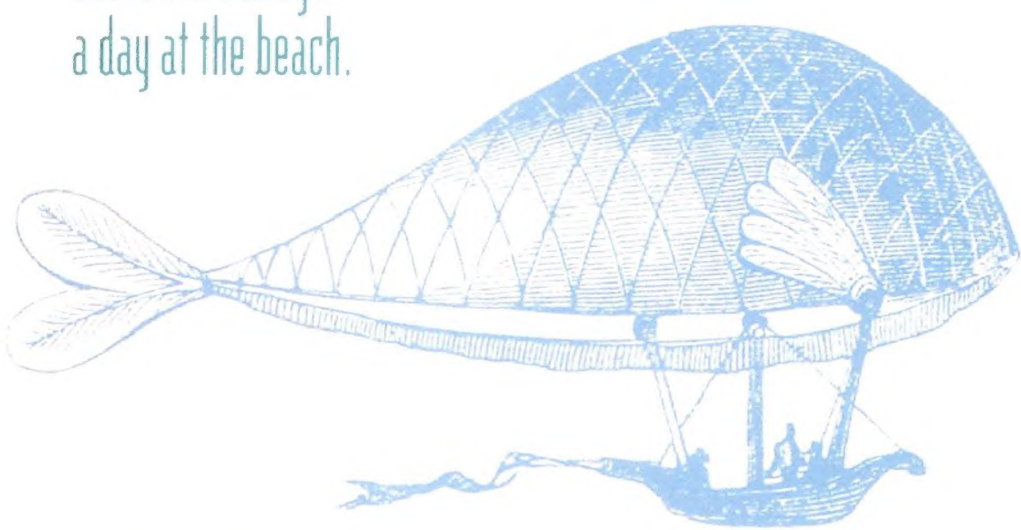

Cover: Wreathed in fog from ultra-cold liquid oxygen, a Lockheed technician prepares a NASA ER-2 for flight in this photograph by Chad Slattery.

Departments

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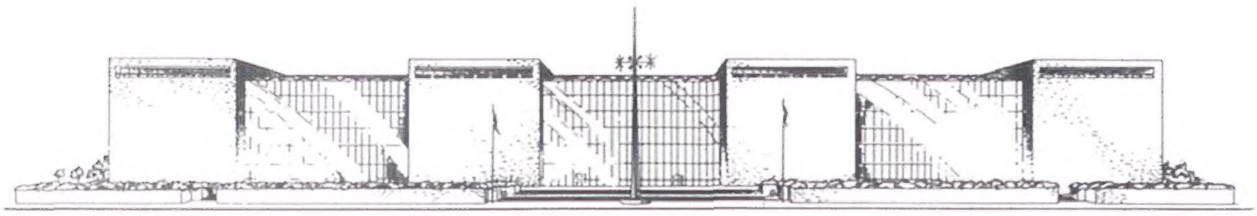

Why Scholarship?

Most visitors to the National Air and Space Museum express surprise when told that we have several departments dedicated to scholarship and research. Two of these departments are historical and are concerned with the history of aeronautics and of space exploration. Another is the Center for Earth and Planetary Studies, which also acts as one of a handful of regional archives where scientists have access to the vast collection of images from NASA space probes. The Laboratory for Astrophysics is actively engaged in astronomical observation and theory. And our Art Department studies the ways in which aviation and spaceflight are portrayed in art and popular culture.

The Museum is fortunate to have such a knowledgeable staff, because our scholars also serve as curators of our galleries. Though the exhibitions we mount may give the appearance of effortlessness, they actually represent dozens of years of work, much of it by researchers ensuring factual accuracy and balance in thought-provoking presentations.

Of course, that is not all. The Smithsonian may be thought of as the nation's attic, but every item now entering our collections has been thoroughly examined to see whether it sheds new light on aerospace industry. Otherwise we must regretfully turn it down for lack of storage space. Once an artifact becomes part of our collections, further research on its preservation helps us to prolong its life as much as possible.

All this research is largely unseen by the public, so its importance may be difficult to appreciate. As evidence of the staff's productivity, published research papers and books are far more apparent.

Research can be conducted in the nation's universities and in government laboratories, and one might wonder why a museum should add to the voluminous research literature already at hand. Part of the reason is that there are no sharp boundaries between scholarship valuable to the public and investigations that are more technical and understandable only to other researchers.

Today's public needs to understand the basis of often abstruse topics that shape our lives and determine our future. The Museum fosters that understanding through exhibitions and large-format films on flight, science, and technology. But to make that kind of information accessible to our visitors, our staff needs to be fully abreast of the latest research.

Particularly valuable to many readers of *Air & Space/Smithsonian* may be efforts that have led in the last five years to the Smithsonian History of Aviation series, a joint program of the Museum and the Smithsonian Institution Press. The series is overseen by an international board that includes some of the finest scholars in the field. Von Hardesty, curator for aeronautics, is the Museum's primary representative in the program.

The first book in the series was Richard Hallion's *Strike from the Sky,* published in 1989. Since then, 15 more volumes have appeared, comprising eight new manuscripts, six reprints of out-of-print classics, and one set of proceedings. They include biographies, business histories, and military studies. The response to this series has been gratifying. For three years running, books in the series have received the Best Non-Fiction Book of the Year Award from the Aviation/Space Writers Association. One of those was aeronautics curator Peter Jakab's *Visions of a Flying Machine,* published in 1990.

Twenty-five years from now, the Museum's present exhibitions will have been replaced by newer ones, but the books we publish will still be around to provide insight into the history of aviation and spaceflight.

Two hundred and fifty years from now, the books may be long forgotten, but the airplanes and spacecraft our research has helped to preserve will still be there. And that makes our research especially rewarding.

—Martin Harwit is the director of the National Air and Space Museum.

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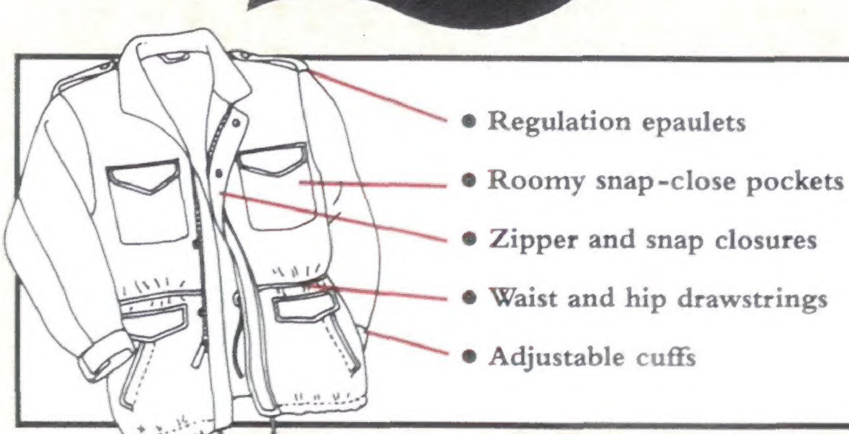

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LETTERS

Those Crazy Test Pilots

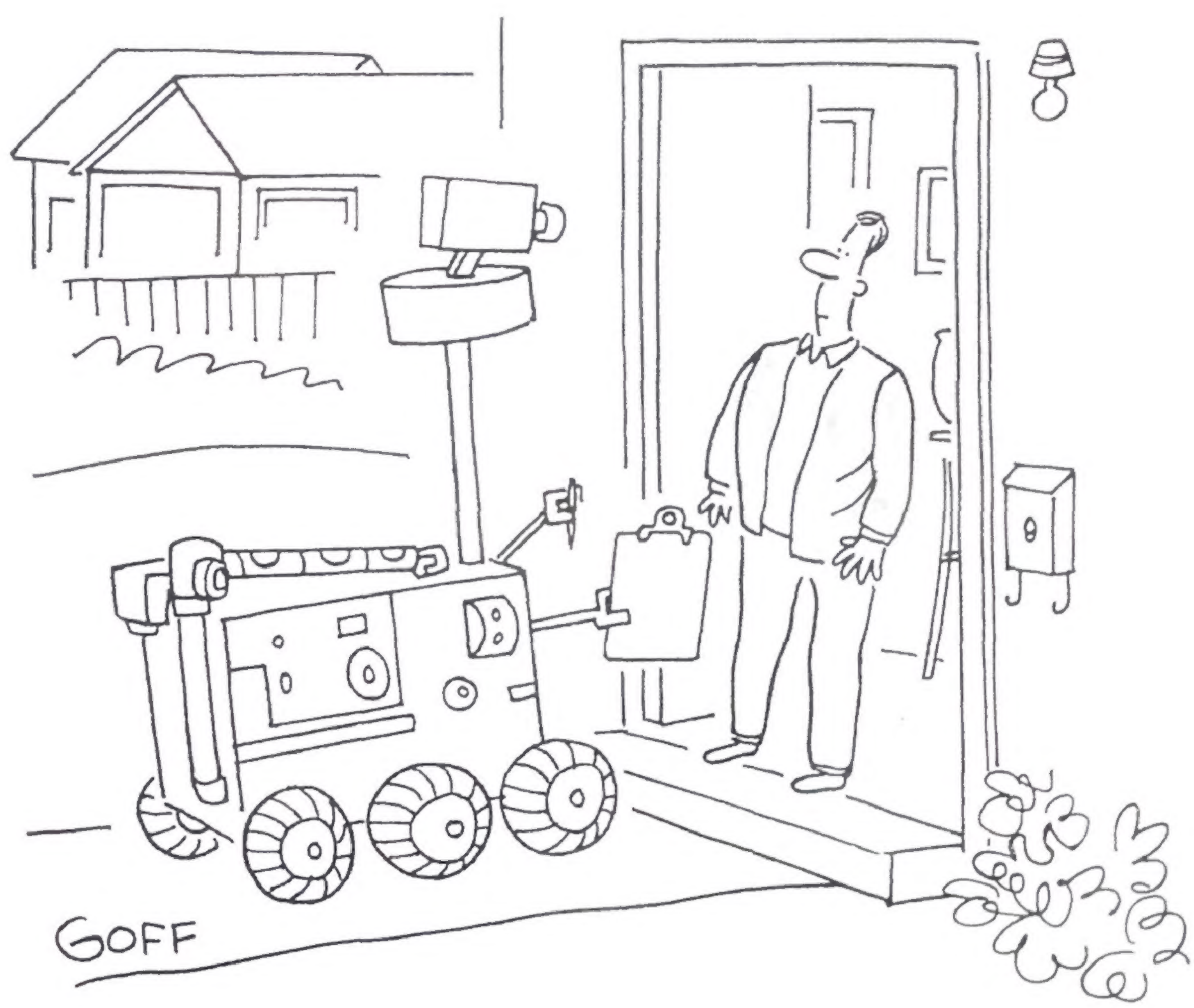
Test pilots are a breed unto themselves ("Fast Track," June/July 1993). In the early 1950s, Republic Aviation sent me to Muroc Dry Lake to help sell the F-105 Thunderchief to the Air Force. One day we decided to test the F-105's stability and handling. Once these tests were completed, the pilot started in for a landing, but he couldn't get the gear down. He was told to abandon the aircraft over the desert. He refused, instead flying in circles until he had used up his fuel. He was directed onto a concrete runway. As he landed, a cloud of smoke, ground aluminum, and concrete billowed about the aircraft. A quality control inspector and I took off in a jeep and headed toward the F-105. Hearts pounding, we pulled the canopy lock switch and reached inside the cockpit for the pilot. Instead of being glad to see us, he cussed loudly and told us to stop bothering him. He said he had work to do. For the next several minutes, as we huddled on the wing scared to death that the F-105 was going to blow, the pilot calmly threw switches and jotted down information. Only when he was finished did he allow us to help him.

Hubert F. Cooper
Bonne Terre, Missouri

Toilet Trouble

I thoroughly enjoyed Beth Dickey's lighthearted description of the space shuttle toilet (Flights & Fancy, April/May 1993). The $30 million toilet is indeed a wonder, but, as astronaut Bonnie Dunbar noted, "If the toilet stops today, you come home tomorrow."

In a space program noted for



"Good afternoon. I'm gathering signatures in support of an unmanned Mars mission."

redundancy, a mission should never be terminated because of toilet calamities. Each shuttle should carry backup waste-collecting devices similar to the ones used on spaceflights in the 1960s: plastic bags with adhesive openings. A germicide in the bag prevented the formation of gas and the growth of bacteria. After use, the bag was sealed and stored in an empty food container. Use of old-fashioned bags, while obviously not the preferred method of waste collection, would sure beat terminating a half-billion-dollar mission because of a malfunctioning toilet.

W. David Edwards
Winston-Salem, North Carolina

NASA's White Elephants

I would like to respond to the essay "It's Time to Go Supersonic" by Daniel S. Goldin (June/July 1993). I'm an aerospace engineer who recently spent several years at NASA's Langley Research Center working with the branches responsible for the present High Speed Civil Transport research program. My perception of the undertaking is that it is a 30-year-old white elephant with a life of its own. There is little coordinated development of conventional or innovative design concepts, which means that the propulsion, structure, and other aspects of different concepts can rarely be compared on a common level. Because of competition and a lack of communication

A Plea to Fellow Aviation Buffs

My name is Sasa Kolombo. I'm a student of English and sociology at the University of Zadar in Croatia. The reason of this letter is my attempt to continue my hobby, which was abruptly stopped after my house and library were burned down during the attack on my town. Now I have nothing. My hobby is aviation, particularly the World War II era. The prices of the books I want to get hold of here are enormous. I would be so grateful if you could send me anything that would help me renew my collection: magazines or magazine subscriptions, books, pamphlets, and posters. Anything that you could send would mean a lot to me. Thank you very, very much.

Sasa Kolombo
Studentski dom
soba 8
Petra Svacica 9
57000 Zadar
Croatia

If my dad were in charge of taking pictures with the Hubble.

within NASA, research is often duplicated, especially when a program has had such a long life that people forget that something was already done 10 or 20 years ago. Most importantly, one gets the feeling that manufacturers become involved with a particular program only to secure NASA research money. They certainly don't seem to jump to spend their own money on HSCT research.

Given that aeronautics gets less than five percent of NASA's budget, is it really wise for NASA to continue extensive studies of supersonic transports while treating less glamorous subsonic research like a poor sister? The most effective ways to expand this country's air transport capacity are to reduce airport noise by improving engines or developing high-lift devices, and by improving air traffic control procedures. While basic research will always have value, let's see NASA spend our money on projects with near-term benefits: improving air transport capacity and re-establishing NASA test facilities as the best in the world.

Name Withheld by Request

Although I share Daniel S. Goldin's vision, I cannot support his contention that NASA's business is to share the risk (read: dollars) in the development of commercial supersonic aircraft. Only the private sector can determine if there is a demand for supersonic transportation. Why should taxpayers believe NASA knows more than Boeing or Airbus about the potential marketplace for said aircraft?

David P. Dutra
San Diego, California

An Astronaut Remembers

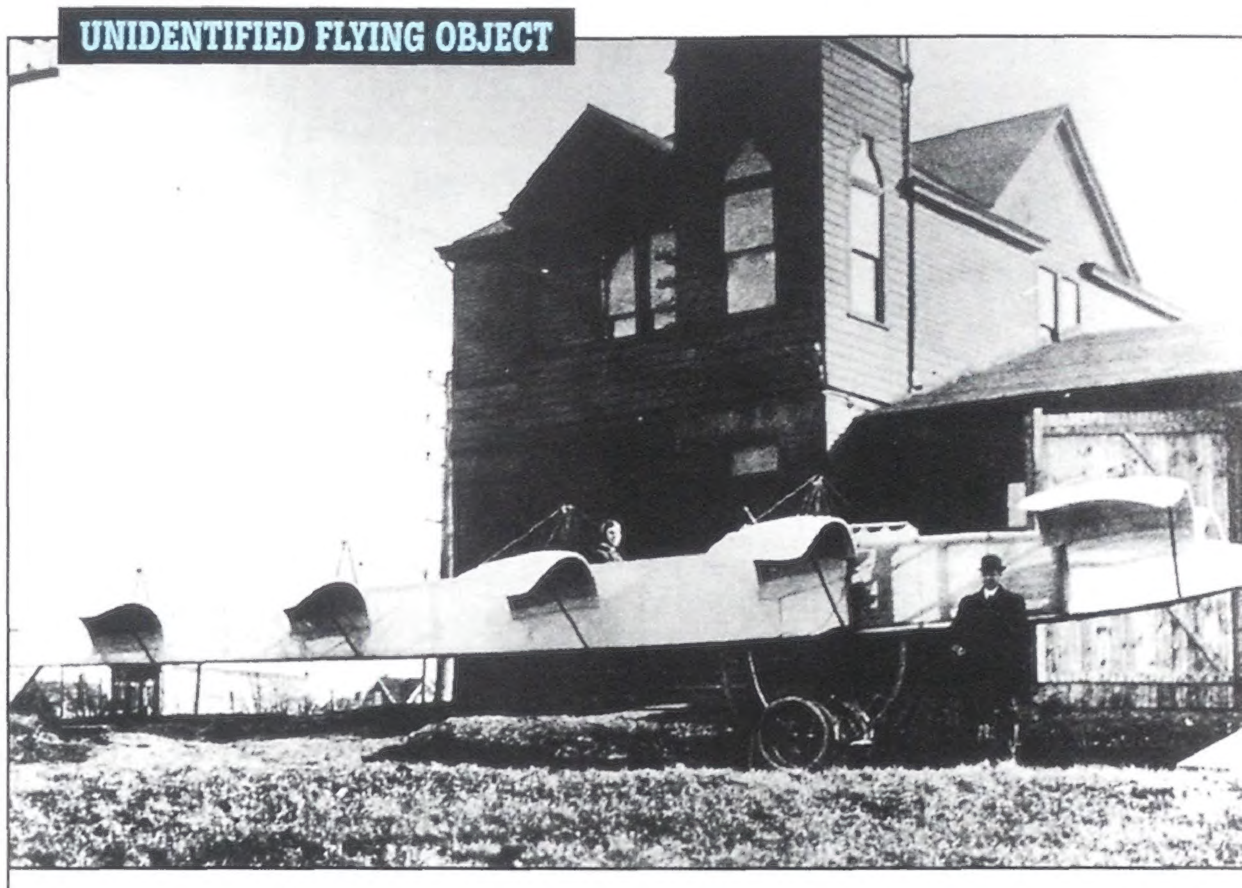
I read Homer H. Hickam's article "Charlie and the Aquanauts" (June/July 1993) with great interest. Charlie Cooper's vision and hard work have made many contributions to the advancement of extravehicular activity. One advancement that Hickam did not mention was the first (to my knowledge) practical application of this method of training. During the Gemini program we found out EVA was more difficult than we had anticipated. We astronauts did not fully appreciate Newton's third law of motion: to every action there is an equal and opposite reaction. Simple tasks proved most difficult to accomplish. Every time a spacewalker touched the spacecraft, it would repel him with the same force. Astronauts became tired and overheated trying to accomplish their assigned experiments. Finally, by Gemini 12, we realized that better hand and foot holds and tools had to be developed if we planned to continue EVA. The Manned Maneuvering Unit, originally assigned to be tested on Gemini 12, was canceled. Instead, a platform was built at the rear of the spacecraft containing newly designed hand and foot holds, plus tools to be evaluated during EVA. How should we train for this evaluation? A swimming pool at a boys' school in Baltimore, Maryland, was acquired. In the fall of 1966, a crude mockup of the spacecraft with platform attached was placed at the bottom of the pool. Buzz Aldrin put on a Gemini training spacesuit attached with air and communication umbilicals plus a scuba diver's lead weights. I sat on the edge when Buzz entered the pool and we went through the entire EVA timeline. The training was successful: on the actual flight Buzz set a new EVA record of over five hours.

James Lovell
Commander, Gemini 12
Horseshoe Bay, Texas

Lindbergh's Political Woes

I wonder if those who wrote to protest my views on Charles Lindbergh have undertaken a close reading of his *Wartime*

UNIDENTIFIED FLYING OBJECT

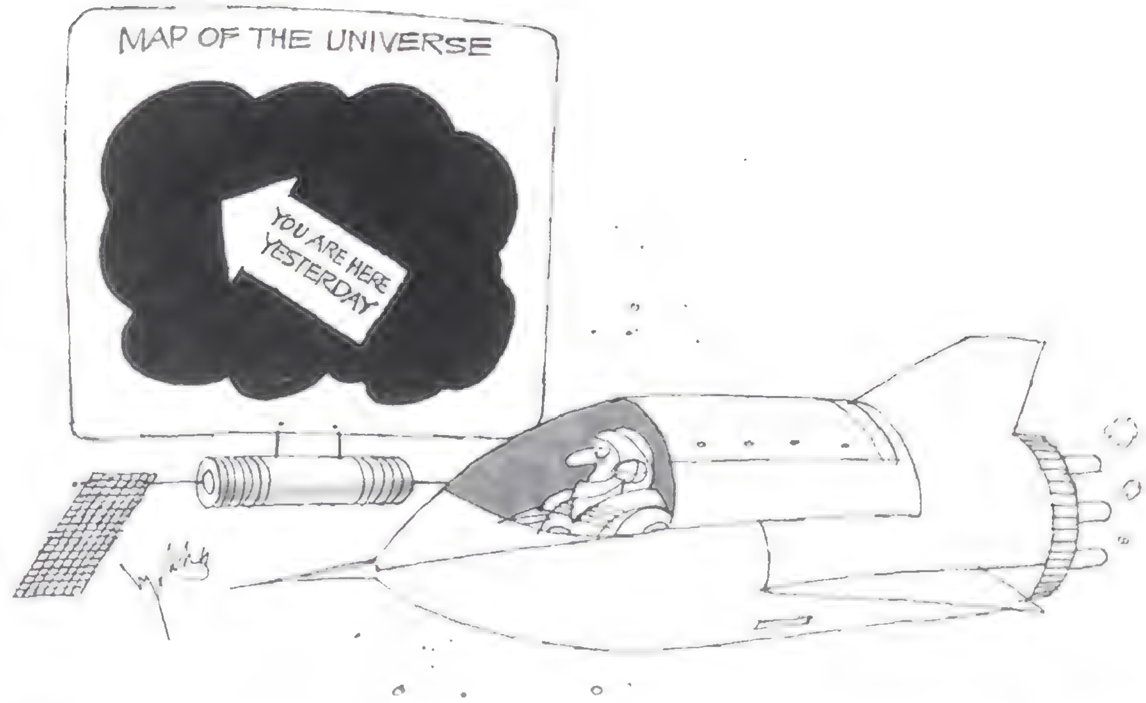


Can you identify the aircraft in this photograph? From time to time the National Air and Space Museum's archives division receives photos that its staff cannot identify. They would appreciate any help in identifying this unusual machine. Nothing is known about the locale. Perhaps the aircraft, which had a four-bladed propeller, was constructed in the building attached to the house, as there appears to be a ramp by the large open door. The two-story building in the background may have been a fire station. If you can solve the mystery, send your response to Air & Space/Smithsonian, *Department ASP, 370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024.*

Last issue's Unidentified Flying Object was correctly identified by eight of our readers. The aircraft is a Fokker M.10E. As to its being marked twice with the German national insignia, many speculated that the double marking was done to improve recognition in the air.

Journals or, for that matter, my book *Loss of Eden* (Letters, June/July 1993). I do not question that Lindbergh's motives for going to Germany were patriotic. He was rightly horrified at the prospect of a war that would kill millions while leaving the Communists in a position to dominate much of Europe. Many of Lindbergh's views, including the belief that peace could be negotiated between England and Germany, were shared by astute observers like Truman Smith at one time or another. What set Lindbergh apart was the rigidity and narrowness of his thinking. How can one explain why a self-professed student of the German scene in the late 1930s never discussed the role of the Nazi party? Lindbergh himself compared his mind to a spinning projectile: once set in motion, its trajectory was beyond even his control. This quality served him well as a pilot and in the laboratory, but it proved disastrous in the realm of politics.

Joyce Milton
Brooklyn, New York



Corrections

The In the Museum section of the June/July 1993 issue mis-characterized an 1857 archival photograph. The photo shows a balloon inflated with gas, not hot air.

In the June/July 1993 Soundings, the photograph on page 13 shows lightning striking a catenary wire, not the space shuttle *Columbia*.

Contrary to a statement made in "Is Something Out There?" (April/May 1993), the constellation Scorpius—in its entirety—is visible to observers located as far above the equator as 40 degrees north latitude.

We welcome comments from readers. Letters, which may be edited, must be signed and include a daytime telephone number. Typed letters are preferred. Write to Air & Space/Smithsonian, *370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024.* Air & Space *is not responsible for the return of unsolicited photographs or other materials.*

Restoring Freedom


CAROLINE SHEEN

One by one, it seems, American values are being restored. First there was Liberty in New York, now Freedom in Washington. The statues, that is, both stalwart women worn by a century or more of exposure to the elements. Liberty received her facelift right on her pedestal in New York Harbor in the mid-1980s, but before Freedom could be cleaned and repaired this year, the 19.5-foot, 7.5-ton bronze figure had to be removed from the top of the U.S. Capitol. Enter a large orange helicopter named Bubba.

One morning last May a Sikorsky S-64F rose quickly from the Capitol grounds and hovered above the dome. With the aid of a gyro-coupled flight control system, pilot Max Evans held that spot in the sky while a rigging crew on the dome attached four dangling cables to a framework of bars and nylon straps that supported the statue. With the connections secure, the helicopter's hoist began lifting, threading the statue through the scaffolding that had been erected around it. The statue swayed slightly but did not twist on the short trip down. Erickson Air-Crane, which operates Bubba, has a suspension system that ensures the load turns only with the helicopter.

The Skycrane has three pilots, two facing forward, one aft. The aft pilot sits in a glass-enclosed booth, looking directly at the hoist. The aircraft is under his control as the cables are attached to the payload and the lift begins. Once all obstacles are cleared, the pilots in front take over.

A cheer rose from hundreds of onlookers as the helicopter lowered the statue to the ground and workers bolted it to a metal base constructed on the Capitol's East Plaza, the statue's temporary home. The three pilots, wearing tan jumpsuits, stood by their helicopter and received some rare public adulation. "We were in Columbus last week on a much more difficult job," said Dave Cox with a grin. "We lifted a transformer through a narrow opening and carried it a block, and no one said a thing."

This was the first time Freedom had been moved since 1863, when pieces of the statue were first hoisted atop the dome by steam engine and bolted together. It took less than 10 minutes to lift the statue off the dome, but the operation concluded a classic Washington fracas that had dragged on for weeks. The Mississippi National Guard was pitted against the helicopter industry for the privilege of decapitating the Capitol. Sonny Montgomery, a powerful Mississippi congressman, led the charge for the Guard against the Helicopter Association International. Each side claimed it had better equipment and the lowest cost. Ultimately, the Department of Defense said that Guard units shouldn't compete with private firms, and Erickson got the job. The cost of removing and later replacing the statue is $60,000.

With that issue settled, Washington needed something else to argue about. Some commentators started declaring that when the statue is returned to the dome, it should face west rather than its previous eastward gaze, so that it reflects the westward expansion of both the city and the nation. Preservationists protested. "Perhaps we'll have it rotating, like a revolving restaurant," joked Bill Raines, spokesman for the Architect of the Capitol. He then hastened to make clear that Freedom would be returned to her original position.

—Lester A. Reingold

UPDATE

Maiden Flight

The Spacehab laboratory module, carrying 22 experiments, made its first flight in the payload bay of the shuttle *Endeavour* last June ("How to Succeed in Business Without Really Flying," April/May 1991). On the second day of the mission, Spacehab investor Mitsubishi announced that it will lease space in the laboratory in 1996.

UPDATE

Departures

Former Apollo-Soyuz astronaut, NASA manager, and space-enterprise executive Deke Slayton succumbed to a brain tumor at his home in Houston, Texas, last June at age 69 (Soundings, June/July 1989).

Actor Richard Webb, who played Captain Midnight in the 1950s TV series ("The Flight Against Evil," December 1987/January 1988), died of a self-inflicted gunshot wound last June at his home in Van Nuys, California. He was 77.

Remember Los Alamos

Los Alamos, New Mexico, is the sort of place where, when the motels are full, the townspeople put you up in their homes for free. It is also the place where the first atomic bombs, dropped on Japan in the second world war, were built. Last June, the men and women who assembled them gathered on a mesa an hour's drive northwest of Santa Fe to celebrate the 50th anniversary of the founding of Los Alamos National Laboratory.

It was a reunion of survivors. Ten years ago, at the 40th anniversary, the master of ceremonies had made a good news/bad news joke about the 50th not being as crowded. Sadly, of course, he turned out to be right. Most of the renowned scientists who put Los Alamos on the map—Robert Oppenheimer, Enrico Fermi, Isidor Rabi, George Kistiakowsky—are now gone.

One oldtimer who was at the 50th, physicist Edward Teller, an inventor of the hydrogen bomb, reminisced in a lecture and gave a piano recital as part of the ceremonies. Some thought it ironic that Teller, now 85, played such a prominent role in the reunion, since it had been Teller's testimony against Oppenheimer, the lab's first director, that got "Oppie's" security clearance revoked in the 1950s. For many years Teller had not been welcome at the lab. Returning to Los Alamos was, he acknowledged in his lecture, "a greater and greater pleasure as time goes by."

At an evening dance, where a swing band played "Moonlight Serenade" and other Glenn Miller tunes, the silver-haired survivors included James Osborn, a staff sergeant at the lab half a century ago who was still able to fit into his old uniform. On his tunic was the patch that the Army had given all its soldiers who worked on the Manhattan Project. It depicts a mushroom cloud rising, genie-like, out of a lightning bolt emanating from a split atom. Shortly after the bombing of Hiroshima, Osborn and a colleague, Harry Daghlian, had been conducting experiments with a critical mass of uranium in a dangerous procedure that physicist Richard Feynman had dubbed "tickling a sleeping dragon's tail." One evening, while Osborn was at the movies, Daghlian returned to the workbench alone and accidentally triggered an atomic chain reaction, showering himself with neutrons. He died on September 15, 1945, one month after the Japanese surrender. Osborn retired from the lab in 1981 and still lives in Los Alamos. "I never spent a boring day at work," he told me.

Another oldtimer at the dance had helped fabricate the plutonium core for "Fat Man," the bomb dropped on Nagasaki. He told me in detail—a little too much detail, I thought—the weight, dimensions, and composition of his handiwork. Now in his 70s, he's amused that the Iraqis still haven't figured out how to do what he had done at 20, fresh out of Ohio State.

—Gregg Herken

MINISTRY OF DEFENCE

Doomed Domes

By the end of the year, one of the icons of the cold war will vanish from the bleak North Yorkshire moors in England. Known to locals as "the Golf Balls," the three housings for the 84-foot dishes of the Royal Air Force Flyingdales radar station are being dismantled. The radar and radomes were erected on a ridge in the heart of a national park in 1964, after a beeping Sputnik convinced Western leaders that they needed an electronic screen to detect intercontinental ballistic missiles.

The passing of the geodesic domes is being mourned by locals and tourists alike. Initially viewed with extreme suspicion—there were fears that "death rays" from the domes would set fire to the heather, kill birds in flight, and disorient homing pigeons—the Golf Balls became a major attraction and appeared on a best-selling postcard.

When word got out that the Golf Balls' days were numbered, English Heritage, the government body that protects buildings of national value, was inundated with requests to preserve them. The agency was unable to do anything: the domes' fiberglass and asbestos fabric had been replaced so often that there was effectively no original structure left to preserve.

The huge electro-mechanical radars that the Golf Balls protected have been replaced by a phased-array system housed in a gray three-sided shape that the locals have nicknamed the Toaster after a power surge from the radar burned out a TV film crew's cameras. The RAF regularly shows scouting troops, housewives, and model building groups around the new station, explaining the capability and reliability of the new arrays, "partly to avoid the rumor-mongering and speculation that caused so many ridiculous stories to circulate when the station was first opened," says station commander Mike Speed, "and partly because we live in a time—thankfully—when openness about what would previously have been regarded as a state secret is now encouraged." Regardless, rumors still circulate but of a more sophisticated variety: "Doomwatch Radar Endangers Cars," blared a newspaper headline after stories surfaced that the new radar would disrupt antilock braking

systems and burn out engine management systems.

Will the new $350 million shape be taken to heart like the old ones? "Come back in 20 years' time," says RAF operations commander Sherry Davies. "They'll think just the same about this one as they did about the Balls."

—*Stephen Bloomfield*

UPDATE

Turns on a Dime

The X-31 performed a high-angle-of-attack, post-stall, 180-degree turn called a Herbst maneuver at Edwards Air Force Base last April ("Stall Tactics," April/May 1991). The maneuver, which relies on the vectored-thrust system that the late X-31 designer Wolfgang Herbst saw as the purpose of the aircraft, calls for the X-31 to reverse direction in nine seconds by using the entire airframe as a speed brake.

The Sky Is Falling

For years, classified U.S. military satellites have been recording flashes from meteors in Earth's atmosphere. System operators, more interested in tracking enemy missiles, have paid them little heed, but now the Air Force Space Command is allowing the records of past meteor sightings to be released to scientists, who say they offer a powerful new tool for counting the number of small asteroids raining down on the planet.

Infrared sensors on early-warning satellites routinely detect the explosions of asteroids as the objects scream into the atmosphere. With energy equivalents of up to 20 kilotons of TNT, some of the explosions seen to date match the power of the bomb dropped on Hiroshima in World War II. Between 1975 and 1992, satellites recorded 136 such events—and those were only a portion of the explosions that occurred. The satellites are designed to track missiles, not asteroids, and the computers that sift through the data are programmed to weed out signals from meteors. "Unless an operator is looking at his screen, sees this thing happening, and then records it, it gets tossed," says Ed Tagliaferri, formerly a physicist at TRW and now a space program consultant.

Tagliaferri, along with Congressman George E. Brown of California, is leading a campaign to have the satellites keep this data routinely. All it would take, he says, is reprogramming the computers to note the meteor sightings.

Tagliaferri says the satellites can detect objects the size of a marble as they burn up in the atmosphere, though the computers would likely be programmed to record only the largest events. Most of the explosions seen so far have occurred at altitudes of 18 to 31 miles and are "pretty much evenly distributed around the globe," he says. Based on the amount of energy released, scientists guess that some of the incoming asteroids have been as large as 200 feet in diameter when they broke up. The large number of meteors recorded supports recent ground-based observations suggesting that many more asteroids are crossing Earth's path than once believed—perhaps 10 or even 100 times more.

The value of these military satellites is that they can easily watch for meteors around the world, even over vast stretches of ocean. And unlike telescopes, they can detect meteors during the day. The satellites "see all the time, essentially 100 percent of Earth's surface," Tagliaferri says. "That capability has just not existed in the scientific community."

Keeping mum for years about such an exciting research tool has not been easy, says Tagliaferri, who worked on the design of TRW's early-warning satellites and has only recently gotten permission from the Air Force's Space Command to make the existing meteor data public. "It's been frustrating," he admits. "On the other hand, I'm also aware of the importance of the [military] mission, and I'm absolutely unwilling to compromise that."

—*Tony Reichhardt*

Through a Glass Brightly

A fighter pilot is just one warm body in a very busy airplane, and with all that information in the cockpit, new ways have been invented to manage it all. Fighter pilots also hate to take time away from looking for adversaries, and instrument panels demand too much "head down" time. A head-up display, or HUD, takes some of the information presented on the panel instruments and projects it as lighted symbols on an optical combiner in the windscreen. The data and symbols seem to float out in front of the airplane at infinity, where the pilot's eyes are focused. Even civil aircraft are finding applications for HUDs in flying instrument landings during conditions of very low visibility.

Now Hughes Aircraft Company, a division of General Motors and a long-time military contractor, has taken elements of the HUD and redesigned it for police cars. The company presented the case for its DataVision system at a Washington, D.C. press conference last spring.

Small wonder that those big fat Chevy

As a result of Hughes Aircraft's turning swords into plowshares, the head-up display that gives fighter jocks the edge is now turning up in police cruisers.

Caprices most state troopers drive look like they're bulging. It turns out Smokey has as big an information load as a fighter jock. In looking for new markets for its HUD smarts, Hughes discovered that the cop on the interstate beat has the traditional voice radio, a data modem and video terminal for such chores as computerized license plate checks, radar and laser speed sensors, plus newly added video cameras to record drunks failing to walk a straight line. Add keyboards to enter information to the gendarme computer net, and you end up with policemen driving down the highway while fixated on a computer display—very dangerous.

Hughes takes all the information from the data terminal, plus calls from dispatchers, radar speed readouts, and emerging technologies such as night vision devices and video maps that locate stolen cars, and sends it all through a compact projector mounted on the car's ceiling. A small semi-transparent combiner about the size of a rear-view mirror, mounted on the windshield, focuses the video image about 11 feet in front of the car, so the driver's eyes never have to shift focus.

The system is already on trial in several states, and a national network of distributors is ready to supply them to your local fuzz as soon as testing and final product development are complete. Moving map navigators, collision-preventing sensors, and even voice recognition ("Computer, get me DMV") are coming in the latter part of the 1990s, says Hughes. And after they equip the cops, it's on to the trucking industry and then agriculture—all those farmers driving combines. Although Hughes says it doesn't have anything this sophisticated planned for the family car, this *is* part of GM we're talking about. See your license and registration, please?

—George C. Larson

UPDATE

GPS Goes Public

Last June, as the first move toward implementing the Global Positioning System in the nation's air traffic system, the Federal Aviation Administration approved civilian use of the GPS for en route navigation and landings made under Visual Flight Rules ("You Are Here," June/July 1992). The first commercial test of a differential GPS is in progress at Wittman Regional Airport in Oshkosh, Wisconsin.

NASA

Slouching Toward Liftoff

The highway to space is getting a much-needed overhaul. The original route, 6.3 miles of "crawlerway" from the Vehicle Assembly Building to the launch pads at the Kennedy Space Center in Florida, was completed by the U.S. Army Corps of Engineers in 1966. Since then, every Saturn V rocket and shuttle flight has taken the route to Kennedy's twin launch pads. All have been transported on 20-foot-tall crawler-transporters with load beds the size of baseball diamonds. Adapted from strip-mining excavating machines, the diesel crawlers get a third of a mile to the gallon turtling down the gravel road at 1 mph. Though the road is made up of eight feet of sand, crushed limestone, and river rock, as repaving team leader Perry Becker points out, "If you take 18 million pounds repetitively over anything, you're eventually going to have to refurbish it."

Rainwater pools on the surface indicate that the limestone base, though hard as cement, has sunk as much as a foot. To refurbish the crawlerway, which is as broad as an eight-lane freeway, contractors will dig down to the base, smooth it out with a new layer of crushed limestone, and spread new river rock on top. The uneven pavement has been causing structural problems on the crawler-transporter, says Becker, adding, "You don't ever want to have a bad day with the crawler."

The crawlerway is one of 26 space program facilities on the Department of Interior's list of National Historic Landmarks. But Becker is too busy stockpiling 75,000 tons of rock to ponder the historical implications of the three-year, $5 million project. "It's held up well," he says, "and if they get another 30 years out of it, then I think it will have done its job."

—Beth Dickey

An Award to Avoid

Aircraft accidents aren't really accidents. So says the Ostriches Anonymous Association, a group of aviation safety enthusiasts who bestow annual "Head in the Sand" awards on aerospace industry figures caught ignoring risk.

The basic premise of the association, says Robert O. Besco, an aviation psychologist and former airline pilot, is that all aircraft accidents today are preventable. Besco founded the Dallas-based group in 1990 with the help of aviation safety expert Jerome Lederer. "Any single decision to bend the rules…will almost always have a benign result the first time. It is when these principles are repeatedly ignored or when

DAVID CLARK

several individuals bypass independent safety mechanisms that accidents will occur," says Besco.

Some 130 Ostrich watchers scan newspapers and TV and spy on their bosses, always alert for outrageous statements or actions the association defines as "head in the sand behavior." Members are pilots, air traffic controllers, engineers, executives, lawyers, teachers, journalists, and even FAA employees. And they prefer to remain anonymous.

Lederer maintains that "you can save more lives by poking fun at oversights than by poking sticks at mistakes." Hence the annual Oliver Ostrich Award, which "will only be offered to those individuals who cannot be positively identified by their award-winning decisions or statements," according to an association news release. "The purpose is to enlighten and entertain, never to embarrass." The Ostrich watchers publish a list of winners and nominees in which all quotes and references are "paraphrased and sanitized to preserve anonymity," Besco says.

Last year's Oliver went to a chief engineer at Boeing who said, "When you have two engines, you have two engines that can come apart. When you have four engines, you have four engines that can come apart. So the less engines, the less possibility you have of any engines coming apart." The 1990 winner was an airline pilot's defense attorney who insisted, "My client's high blood alcohol content did not degrade his flight deck performance. He is an alcoholic and has a high degree of tolerance."

The association's goal, says Besco, is to get everyone in the aviation industry to "assist in making the world a safer and better place in which to fly by getting all heads up, alert, and out of the sand."

—Beth Dickey

Rooms on the Fly

Missed the Oshkosh fly-in? Not to worry: that's not all the aviation Wisconsin has to offer. Just drive to Dodgeville, an hour west of Madison, and check into the Don Q Inn. You can't miss it—it's the motel-restaurant with the Boeing C-97 on the lawn. You know, the four-engine transport with the big "Q" on the tail and Farrah Fawcett's autograph on the fuselage.

The C-97—in civilian terms, a Boeing 377 Stratocruiser—was brought to the Dairy State from California in 1977 by Don Quinn, the motel's owner and namesake. The C-97 and Fawcett were featured in a TV ad for the Mercury Cougar, and the actress autographed the

airplane. Quinn's intent was to convert the craft into a coffee shop, but it became such a tourist draw that he kept it intact.

The Don Q Inn is also part of the FantaSuite chain, which features a number of fantasy suites. Two of the Don Qs are called "Tranquility Base." The motel's newsletter explains, "Named for the location where United States astronauts landed on the moon, this is the ultimate intergalactic getaway. Featuring a recreation of a Gemini Space Capsule poised on its landing gear, this suite is highlighted by a 10-sided waterbed, AM/FM stereo, TV, VCR and video games, all inside the capsule! Directly underneath your spacecraft is a 'moon crater' whirlpool." One of the Tranquility suites has an astronaut mannequin in residence. "We call him Neil Armstrong," says manager Pat Horner. "He doesn't do much though." Balloonists should delight in another two-story suite named "Up, Up and Away," featuring an actual balloon in whose basket reposes a bed, TV, VCR, and video game player.

Quinn died a couple of years ago, but his legacy endures in his unusual hostelry, which includes a lobby with 1950s-era barber chairs arranged around a fireplace fashioned from a ship's boiler. Other notable features include a 67-foot-high outdoor sculpture made from wagon wheels welded into a vaguely tree-like shape, and a tunnel excavated through artifact-laden limestone that links the motel lobby to the restaurant.

On weekends the specialty suites go for $229 a night—a bit steep for farm country, but then, this isn't your ordinary motel. However, adds Horner, you can't stay in the C-97 overnight. "Everyone asks, but at the present time, no."

—*Wes Eichenwald*

UPDATE

X-30 Axed

The U.S. Air Force and NASA have canceled the scramjet single-stage-to-orbit X-30 National Aerospace Plane transport ("Space Plane," August/September 1986). The project is being redirected from achieving manned hypersonic flight toward solving technological and financial issues that stand in the way of constructing a flight test demonstrator, such as determining the boundary layer transition point, studying scramjet performance data at high Mach numbers, and obtaining proof of hypersonic vehicle stability.

First Look


JON LOMBERG/NASM

When the National Air and Space Museum commissioned me early last year to paint a mural of the Milky Way, I was astonished to learn that no map of the galaxy existed. All previous depictions of the Milky Way had been merely generic approximations. My painting would be the first to show how the many objects familiar to astronomers and others who watch the sky—huge gas clouds like the Orion Nebula and star clusters like the Pleiades—are located in relation to Earth and to one another.

I chose a point of view several thousand light-years farther than Earth from the galactic center, and slightly above the galactic plane. This perspective dramatizes the spiral shape of the galaxy and places the neighborhood of the solar system in the foreground so that the objects closest to Earth are more prominent than those farther away, which we have seen in less detail.

Astronomers estimate that there are more than 200 billion stars in the Milky Way, and of course I could neither locate nor render each one. I had only a six- by eight-foot canvas on which to fit the entire galaxy. On this scale the solar system is smaller than a virus. A sphere 100 light-years in diameter—say, about three times the size of the Orion nebula—is a mere one-quarter inch across, almost lost in the tangle of stars. To select objects that would be visible from the imaginary observer's position, I worked with Museum astronomer Jeff Goldstein and Leo Blitz, an astronomy professor at the University of Maryland. Goldstein created a computerized map, plotting on a grid the location of more than 300 clusters and nebulae relative to the sun and the galactic center. It took about six months to determine, check, and refine the coordinates. My task was then to translate the small geometric symbols standing for various nebulae and clusters into portraits.

I started from the position of our sun, nestled in a short "spur" between two spiral arms of the galaxy, and painted outward from that. The tiny shapes from the computer printouts became the Veil, North American, and Rosette nebulae, for example, which share the Orion spur with us and the Omega and Lagoon nebulae in the Sagittarius arm of the galaxy. I executed these portraits of huge nebulae and clusters with a magnifying glass. Slowly the Milky Way's spiral arms of stars began to take shape, and I had the enthralling sensation of being the first human ever to see how our galaxy might really look and truly appreciate Earth's tiny place within it.

Like the maps of Earth made by the ancient Greeks, this map is most accurate close to home, more conjectural farther away. It may be hundreds or thousands of years before Earth dwellers can see a real photograph of our galaxy. For now, the most accurate and detailed picture we have is on display in the Museum's "Where Next, Columbus?" gallery.

—*Jon Lomberg*

Last Dance

Patty Wagstaff shrugged into her aerobatic airplane as if it were a leotard. Amid the F-16s howling around Andrews Air Force Base in Maryland one afternoon last June, the little Extra 260 scuttling to the runway for takeoff looked like an insect. Once airborne, however, the red, white, and blue mid-wing monoplane proved astoundingly nimble as Wagstaff bounded through her aerobatic sequence like a gymnast.

"She really likes snap rolls," her husband Bob Wagstaff explained as he attempted to narrate her performance. The pilot was complicating his job by ad-libbing, punctuating every maneuver with a snap roll or three. The temptation to deviate from the choreography was understandable—this was to be her last flight in the airplane before the two-time national aerobatic champion and airshow star turned it over to the collection of the

National Air and Space Museum.

The German-built wood and composite Extra 260, which has a roll rate of 360 degrees per second, will be installed in the prestigious Pioneers of Flight gallery, the first addition since the *Gossamer Condor* in 1978. "I solicited it because she represents a milestone for women—the first woman to become the national aerobatic champion," says general aviation curator Dorothy Cochrane. "Plus it's a super-state-of-the-art airplane, and

CAROLINE SHEEN ©

we haven't had an aerobatic plane come in for some time."

The wind was gusting to 20 knots at Andrews, instantly erasing Wagstaff's meticulous smoke trails. She flew for about 15 minutes, and as she taxied back to the crowd of reporters and Museum people she kicked the tail around and gunned the smoke one last time.

After handing the airplane keys to Museum director Martin Harwit, who wanted to know what happens to her dangling earrings when she flies negative-G maneuvers, Wagstaff announced, "I feel sadder and more nostalgic than I thought I would."

Her next airplane will be a larger version of the same type. The Extra 260 will be installed in its new home next year for an indefinite stay.

—*Patricia Trenner*

ARTIFACTS

MARK AVINO

Remembrances of a distinguished career, these medals were awarded to General Curtis E. LeMay by the United States, its allies, and its one-time enemies. As commander of the 20th Air Force in World War II, LeMay directed the low-level bombing of Japan and the utter destruction of Tokyo. Yet on December 7, 1961, Japan bestowed on him its highest military decoration, the Grand Order of the Rising Sun (center), for his efforts to rebuild the country. The Soviet Union decorated LeMay with the Order of the Great Patriotic War in 1945. Three years later, as the first head of the Strategic Air Command, he led the U.S. nuclear challenge to the Soviets. LeMay was awarded the U.S. Distinguished Service Cross (bottom right) long before the cold war made him a controversial figure. The LeMay collection is exhibited at the Museum's Garber facility.

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700; TTY: (202) 357-1729.

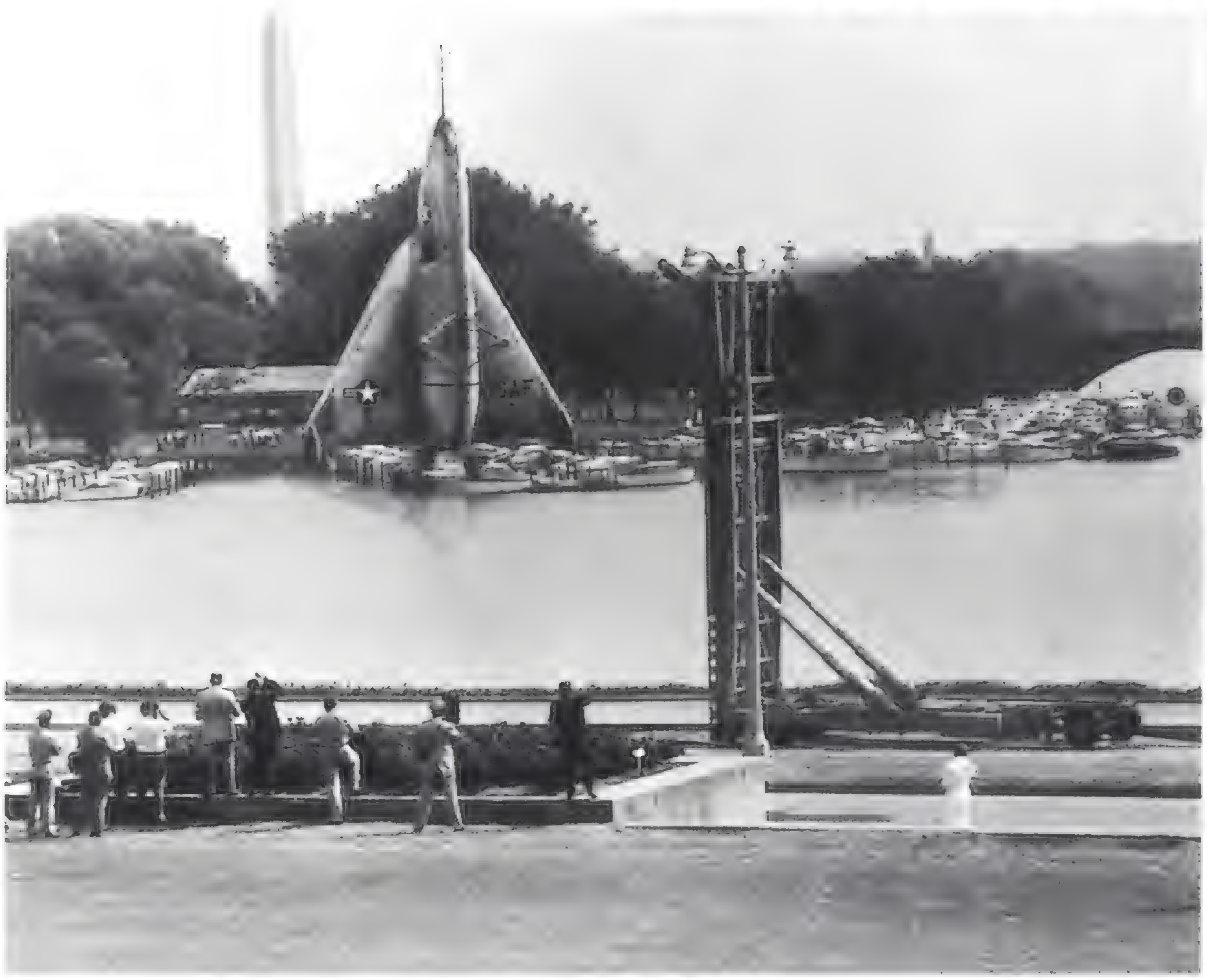
August 7 Monthly Sky Lecture on a topic of current interest in astronomy. Einstein Planetarium, 9:30 a.m.

September A new IMAX film, *Tropical Rainforest*, opens this month. Filmed in Australia, Costa Rica, French Guiana, and Malaysia, the film examines the long evolution of the rainforest, its rapid and recent destruction as a consequence of human intervention, and the scientific efforts to understand the habitat. Langley Theater, selected evenings, 6:45 p.m.

September 4 Monthly Sky Lecture on a topic of current interest in astronomy. Einstein Planetarium, 9:30 a.m.

Extended Summer Hours The National Air and Space Museum opens at 10 a.m. and closes at 6:30 p.m. through Monday, September 6, when it will return to its regular hours, 10 a.m. to 5:30 p.m.

HEDGE HOPPING



RYAN AERONAUTICAL LIBRARY (2)

Despite assurances that all preparations had been made at the landing site, something prompted me to double-check. I settled into the cockpit of the Ryan X-13 Vertijet in which I was about to make the first jet flight to the Pentagon and keyed the mike.

"Paralyze Chase, this is Paralyze One, over" (I never did learn the explanation for that peculiar call code). Paralyze Chase was a B-25 chase plane orbiting south of Washington, D.C., acting as a communications link between me and the ground control station at the Pentagon. "Have they watered the hedge, over?" Chase came back to say that they had, in fact, watered the hedge. I set about squaring away the cockpit, firing up, and getting under way.

The X-13 had already been raised to the vertical and I was about to launch when Chase contacted me to say that maybe they had not watered the hedge after all. I put a hold on the launch to give him a few moments to sort out the situation, and he came back with the news that they had not, repeat, had not, watered the hedge. I came close to blowing a fuse.

There I was, at Maryland's Andrews Air Force Base on a cool July dawn in 1957, sitting in the cockpit of the world's first turbojet-powered vertical-takeoff-and-landing aircraft and feeling frustrated and ticked off, as might be expected when a launch involving maximum effort and questionable outcome is scrubbed. I signalled the ground crew to lower the airplane to the horizontal and killed the engine. All because someone had forgotten to water a hedge.

After landing at the Pentagon, we were to take off the following day on a flight that would duplicate that of the Wright brothers' first military aircraft when it was delivered to the U.S. Army in 1909. One reason we had planned a dawn launch was to avoid causing traffic tie-ups around the Potomac River—the startling appearance, flight path, and behavior of the X-13 could bring motorists to a screeching halt. Though the project had been declassified that April, civilians knew very little about it. Fortunately we were able to arrange for a second try at 10 a.m. rather than having to wait until the next day.

In spite of its unlucky number, the X-13 was quite successful as a research airplane. The single-seat, tail-less, delta-wing aircraft was the first to successfully demonstrate conventional fixed-wing flight, vertical hovering, and shifting between these modes. It took off from and landed on a trailer whose bed was erected to the vertical by large hydraulic cylinders. At the top of the bed a cable strung between two arms secured the aircraft by its nose hook before takeoff and after landing. The thrust of the turbojet engine supported the airplane in the hover mode. A gimballed tailpipe nozzle provided pitch and yaw control and wingtip nozzles enabled roll control. The pilot's seat rotated forward 45 degrees for proper visibility during hovering.

The Pentagon's river entrance fronts a lagoon that connects to the Potomac River. From a raised dock on the south side of the lagoon, an incline led to the street, where the X-13 trailer was parked. Covering the incline was the hedge. Trimmed to about three feet, it sheltered leaves, debris, and loose earth beneath its resilient growth.

The X-13 had to pass over the incline in a vertical hover during the final stages of the landing approach, and if the hedge was not well watered the jet blast might raise enough dust and leaves to cut visibility or choke the engine. I did not want to be brought down by a hedge. The X-13 had limited fuel capacity—there was just enough on board to make the planned flight plus maybe 45 seconds of reserve. Once I left Andrews and reached the Potomac I was committed to either land or eject. If there was a delay of more than 30 seconds after I had reached the hover at the Pentagon I would have to shift to

fixed-wing mode and head west, hoping that the remaining fuel would get me to a clear area where I wouldn't endanger a crowd if I had to eject.

Eventually 10 a.m. rolled around. I fired up, signalled to be raised to the vertical, made a quick check of the jet reaction control system, and called Paralyze Chase. I made a rapid liftoff and transition to fixed-wing flight to conserve fuel and headed west toward the river at 1,000 feet.

After passing Bolling Field I let down to about 200 feet above the river. Just south of the 14th Street bridge I transitioned to vertical, crossed the bridge at 120 feet (traffic had been stopped), and was over the lagoon at 75 feet preparing to land. Then the unanticipated occurred.

The engine jet blast struck the water and threw up a curtain of spray and mist so thick I could not see through it. And the curtain kept rising! I could still see the top of the Pentagon but not much below except for water and some boats on the west side. The X-13 had never hovered over water before, and dust kicked up by the jet blast had never risen so high.

At the risk of worsening the water curtain, I increased thrust and gained some altitude. That would lengthen the landing approach and consume precious fuel, but it was the only reasonable recourse—I had to get the airplane higher and over solid ground. I rapidly made for shore. In spite of the added jet blast, the curtain dropped rapidly. I could see all of the Pentagon again.

As the X-13 passed over the much-discussed hedge at 150 feet, the blast kicked up some leaves and debris but no significant dust. It had been well watered after all. I headed toward the trailer, dodging the flagpoles at each end of the incline. I let down in a non-standard, nearly vertical final approach, inched forward to engage the hook on the cable, and completed the first—and probably last—fixed-wing jet airplane landing at the Pentagon.

—Peter F. Girard

Outfield Fly

The 1943 World Series had all the hallmarks of a classic. In a rematch of the previous year's antagonists, the St. Louis Cardinals would attempt to repeat their resounding win over the New York Yankees. The 1942 Cardinals had not been given much of a chance against the New York powerhouse, but with the batting of rookie Stan Musial and the pitching of Johnny Beazley, they defeated a team that had won six league championships in seven years.

But the nation's war effort was gobbling up manpower at a prodigious rate. No one knew who might be playing ball in 1944, or if there would even be a 1944 season. It looked as if this might be the last great series for the duration of the war, which is why the first game drew over 68,000 fans to Yankee Stadium.

As the teams took batting practice and the pitchers warmed up, four Army Air Forces B-17 bombers were droning toward New York City on their way to combat bases in England. At the navigator's station of *Thru Helen Highwater* sat my uncle, Second Lieutenant Harold Rocketto of Brooklyn. Second Lieutenant Jack Watson was the pilot; the other bombers were piloted by Second Lieutenants Robert Sheets, Elmer Young, and Joseph Wheeler.

As Rocketto, a Brooklyn Dodgers fan, scanned the landscape trying to pick out boyhood haunts in the Bensonhurst section, the idle chatter on the intercom turned to the World Series. No one is sure what sparked the next move. Perhaps it was Rocketto's desire to seek revenge against the Yankees for their 1941 victory over the Dodgers. Then again, perhaps it was just the high spirits of young men facing a dangerous future. Whatever the reason, the fans at Yankee Stadium were about to be treated to an impromptu demonstration of the nation's bomber force.

As the aircraft crossed the Hudson River, the pilots headed for the Bronx and put the formation into a shallow dive. Picking up speed, the bombers thundered over Yankee Stadium in a low pass from home plate to center field. After they climbed out the B-17s wheeled about and circled the field while Watson returned for an encore. He cleared the upper-deck flagpoles by a mere 25 feet, prompting the Associated Press to later report that "an Army bomber roared over Yankee Stadium so low that Slats Martin could have fielded it." Watson then rejoined the formation and headed east.

"We knew we were heading for a

PAUL SALMON

combat zone and dropping in on the World Series seemed like a good idea at the time," Wheeler told a reporter months later. "The announcers must have thought it was part of the show because after we went over the first time we could hear them on the plane radio talking about the big air force review. We figured they were enjoying it so we turned around and came over a second time. We thought nothing about it until later when we found we had caused a sensation."

New York mayor Fiorello La Guardia, a World War I Army pilot, was watching as the bombers swooped overhead. La Guardia initially appreciated the panache of the young men, but admiration quickly gave way to his greater duty as mayor. Outraged, he burned up the phone lines to the Army Air Forces brass. "That pilot should be properly disciplined, endangering the lives of the citizenry of New York in that manner," he fumed.

When they landed at Presque Isle Airfield in Maine, Watson and the three other pilots were confined to quarters while court martial proceedings were undertaken. They were released a few days later when the Army realized it was foolish to keep four badly needed aircraft and crews out of combat because of a youthful indiscretion. "Besides," a general told Watson, "you and your crew will probably be killed anyway."

Five days after the buzzing brouhaha the four aircraft continued their journey to England, each pilot's military record heavier by a letter of reprimand and his wallet lighter by a $75 fine—no small sum to a second lieutenant back then.

Because of wartime news restrictions so tight that sports announcers were forbidden to comment on the weather lest the enemy pick up valuable intelligence, the buzzing incident went almost entirely unreported. The names of the crews were unknown to all but the authorities until three months later.

January 11, 1944, was one of the costliest days of air combat in history. Some 60 U.S. bombers were destroyed and more than 600 airmen were killed, wounded, or reported missing. On that terrible day, Watson, flying with the 303rd Bomb Group, singlehandedly returned his badly shot-up and burning bomber to England. In a radio interview he brought up the stadium incident by voicing hope that the mayor of New York was not still sore at him. After hearing the interview, La Guardia sent Watson a message: "All is forgiven. Congratulations. I hope you never run out of altitude. Happy landings. Will be seeing you soon."

"Thank you, Mr. Mayor, and it can't be too soon for me," Watson replied, then added, "We'd sort of like to go back together some day and drop in on the Rose Bowl game."

—*Hap Rocketto*

ABOVE THE SKY

When NASA's high-flying ER-2s probe the upper atmosphere, their pilots look like astronauts and takeoffs turn into launches.

by Doug Stewart

Photographs by Chad Slattery

Care and feeding of NASA's ER-2s is handled by a crew of 34 Lockheed employees. The airplanes earn their keep by serving earth scientists and by testing new sensor systems before they are lofted aboard satellites.

Tugging on a zipper, Lockheed life support technician Walt Prouty struggles to close pilot Ron Williams' mustard-yellow pressure suit. "There isn't as much material here as there used to be," Prouty mutters, playing the insolent valet. Williams, silver-haired and a little paunchy, just growls. Prouty ignores him and places a pair of thick eyeglasses on the bridge of the pilot's nose, anchoring the frames inside the spacesuit-style helmet. Prouty snaps the face shield shut and Williams is dressed for work. He is also sealed in, and he'll breathe pure oxygen from a suitcase-size unit he'll carry around with him for the next 45 minutes.

At 58, Ron Williams may be a bit weathered for a hot-shot aviator, but he and five other retired Air Force spy pilots are still flying high. Williams and four Lockheed pilots, under contract to NASA, along with one NASA pilot, operate a fleet of three civilian derivatives of the legendary U-2.

The space agency's version is called the ER-2 (for "earth resources"), but aside from wiring and paint jobs—NASA prefers a dazzling white instead of the original dull black—the only important difference between the U-2 and the ER-2 is their payloads. The three ER-2s, based at NASA's Ames Research Center in Mountain View, California, carry only scientific experiments, and none of them is classified.

"There is no spy equipment on these aircraft," says NASA's chief engineer for the ER-2, Andy Roberts, taking great care to emphasize the point. "We travel all over the world with these," he says. "We give tours to politicians and military people overseas. Afterwards they'll take us aside and say, 'What are you *really* using it for?' People are so paranoid about intelligence gathering we have to make sure our aircraft have nothing to hide." NASA even refrained from adopting the military Global Positioning System, which is standard on Air Force TR-1s (a U-2 derivative), to keep people from drawing the wrong conclusions.

In NASA parlance, the airplane is a "high-altitude multi-sensor platform." Proposed research missions are evaluated by an agency committee made up of scientists and managers, and after the selection process, scientists from dozens of universities and government agencies wait in line to send their experimental sensors up—*waay* up. An ER-2's normal cruising altitude is 12 miles above sea level, more than twice the height of Mount Everest.

"The ER-2 operates above 95 percent of the atmosphere and above virtually all of its water vapor and particulates," says John Arvesen, chief of NASA's high-altitude branch. "To a sensor looking down at the Earth, the aircraft may as well be in space." Scientists design-

Dressed like an astronaut, Jim Barrilleaux wears a pressure suit designed for the edge of space. To purge his blood of nitrogen before a flight, he breathes pure oxygen from a portable unit that also keeps him cool.

ing remote-sensing experiments can try them out on the ER-2 instead of waiting years for a rocket. "We like to think of these aircraft as stepping stones to space," Arvesen says.

With their airborne sensors, NASA's ER-2s have kept tabs on snow cover in the Rockies, coral damage in the Florida keys, and algae blooms in numerous reservoirs. High above the disastrous Oakland, California fire of October 1991, infrared sensors aboard an ER-2 helped firefighters on the ground by peering through the smoke and identifying hidden hot spots. Not all the sensors aboard NASA's ER-2s look at objects on the ground, though. Some are designed to extract data from the atmosphere around the airplane. The strongest evidence that the hole in Earth's protective ozone layer is expanding came from air-sampling ER-2s that began flying over the polar regions in 1987.

An airplane capable of cruising at 65,000 feet for nine hours without refueling is no ordinary jet, and in their cavernous hangar at Ames, the ER-2s look like the elite aircraft they are. The nose protrudes well out in front of the delicate centerline landing gear, giving the airplane an eager, inquisitive look. Aft of the tiny canopy, the narrow fuselage, its thin skin concealing a jet engine as powerful as an F-16's (but without an afterburner), sweeps straight

The relaxed, informal atmosphere on the ramp gives way to focused hustle as Ron Williams clambers into the cockpit in preparation for a "launch" (ER-2s never just take off). A roll-away canopy shields him from the sun until he starts the engine and the onboard air conditioning can take over.

back like a missile. The ER-2's most striking feature, however, is its graceful wing—a majestic 103 feet from tip to tip, more than three times the wingspan of an F-16.

Before dawn one morning last winter, people bustle around the hangar readying NASA 709 for a two-hour test flight in preparation for a mission with a name only an engineer could love: Tropical Ocean Global Atmosphere—Coupled Ocean-Atmosphere Response Experiment, or TOGA COARE. From a base in Australia, the airplane will soon help explore the climatic effects of a mysterious region of warm water in the Pacific Ocean northeast of Papua New Guinea. This "warm pool" is thought to drive much of the world's weather patterns. Gizmos for studying the atmosphere's behavior over the warm pool seem to fill every cubic inch of space inside the airplane.

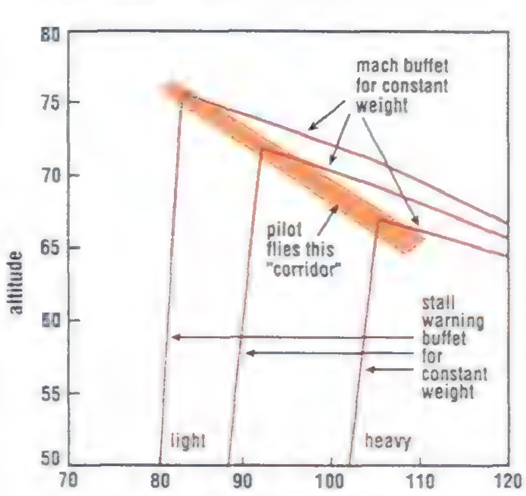
"We really shoehorn these airplanes," says Andy Roberts as he points out some of the hiding places. The aft end of a huge pod under one wing has been pulled away, and an atmospheric scientist is pouring steaming liquid nitrogen from an insulated container into what looks like an automobile's rooftop luggage carrier but is really an infrared sensor. The nose of the airplane has been rolled away on a dolly, revealing a huge box decorated with knobs, buttons, blinking red lights, and digital

The ER-2 is based on a second generation of improved U-2 airplanes that were capable of operating from aircraft carriers, which explains a seldom advertised feature: folding wingtips (left). Ron Williams (below left), like most of the Lockheed pilots who fly under contract to NASA, has a career's worth of military U-2 experience to draw from. NASA's Andy Roberts (below) manages the ER-2 operation in the field—even when the field is far from American shores.

In the Corner

If a subsonic airplane flies too close to the sound barrier, its wing is buffeted by turbulence caused by the buildup of a shock wave. If it flies too slowly, its wing can't produce lift anymore, and it stalls. The heavier the airplane, the higher the stall speed.

The speed of sound drops as the airplane climbs, however, and eventually, an ER-2 reaches an altitude where the stall speed and the speed of sound converge—a point pilots call the "coffin corner." As this figure shows, ER-2 pilots climb as they burn fuel and the airplane gets lighter, flying a very narrow speed range to avoid both the stall and the Mach buffet.



readouts. It looks like one of those computerized bombs James Bond was always disarming in the movies.

Two lightning experts, deep in conversation, wander behind the starboard wing. Suddenly, the end of a black, torpedo-shaped protuberance on the trailing edge revolves half a turn and stops. The startled scientists stop talking and peer at it.

"What *is* this?"

"Your guess is as good as mine."

"Don't touch it!" yells a third scientist, rushing up. The revolving torpedo is actually a radiometer, he explains, and the transparent orange dome over its sensor is made of \$2,500 worth of water-soluble crystal. Even oil from a fingertip would mark it. "Also it's slightly poisonous," he adds. The other two scientists stand clear of the instrument.

While the payload is often the last word in sophistication, the platform carrying it is simple to the extreme. Willie Horton, a genial, heavyset ex-pilot and Lockheed's on-site manager, wouldn't have it any other way. "Among all this high tech, we've got a barbershop fan and a manual fog scraper," he says approvingly, leaning against the back of 709's cockpit from the top of a ladder. Pilots use the scraper, a stick wrapped with felt, to wipe away moisture that condenses on the inside of the canopy during descent. Horton, who's logged 2,400 hours flying military U-2s, points out a short length of string on the outside of the canopy. By glancing up to see how it trails in flight, he says, a pilot can judge whether the plane is trimmed properly or is skidding slightly to one side. "Today's military aircraft

Looking Down on the Environment

Though U-2s were best known for their aerial photos, NASA's versions use more than lenses to see what's on the ground. A mission called AVIRIS (for Airborne Visible/Infra-Red Imaging Spectrometer) recently finished mapping the entire eastern U.S. shoreline. The ER-2 carried a whisk broom scanner: sweeping back and forth 12 times a second, the device recorded images of six-mile swaths of ground. It used an array of detectors, each sensitive to a different spectral band, or color, of sunlight reflected by features on the ground—rocks, soil, water, snow, vegetation. Each picture was made up of 224 visible and infrared spectral bands.

Researchers can combine or subtract different bands to reveal things of interest. For example, when plants grow in copper-rich soil, their foliage gives off a tell-tale signature as it reflects sunlight. A mining company might zero in on good places to dig by carefully searching different map overlays for that signature.

An instrument called LASE, which is set to fly later this year, will look not at the ground but at moisture in the air. It will fire a 20-megawatt burst of laser light straight down, and the energy will be selectively absorbed by water vapor in the beam's path. Almost immediately, LASE will fire a second downward burst of a slightly different "color." This beam will pass right through any water vapor. An onboard telescope will detect "backscatter"—reflected radiation—which indicates how much water is present in the narrow column of air. The device, destined eventually for Earth orbit, should yield rich new insights into weather and climate, including clues to possible mechanisms responsible for global warming.

are too sophisticated to have a yaw string," Horton says in a rich Carolina drawl. "That's why they're grounded so much."

Over to one side of the hangar sits a Batman-black nose cone, a recent hand-me-down from the Air Force. Its underside is bashed in, the result of a landing mishap, but nobody is manufacturing U-2 nose cones anymore, and the Lockheed technicians working for NASA plan to fix it up and paint it white.

Landing a U-2 is a notoriously tricky procedure. "It's like landing a unicycle at 60 miles an hour," says Horton. The U-2 is often described as a glider with a jet engine, and as in a glider, the pilot has to keep flying it even after it's touched down. "If you land in a crosswind," says Horton, "you're kicking your rudder back and forth like this, and pushing your arms back and forth." He demonstrates, looking like a rodeo rider on a Brahma bull. And if you pull the nose up too sharply on landing, he says, you find yourself back in the air.

NASA/AMES

A generous wing, a lightweight airframe, and a powerful engine are the keys to the ER-2's high-altitude performance. A "glider with a jet engine," it's also one of the most elegant shapes in the sky (top). Lockheed manager Willie Horton admires the airplane's simplicity (above). Sensors are NASA's responsibility: here, engineer Paul Racette works on an imaging radiometer (above right).

"Then the slightest bank, and you put your wing on the ground and do a cartwheel."

"The fun part is takeoff and landing," says Lockheed pilot Bill Collette. "The shorter the time between those, the better I like it." Once the pilot reaches 65,000 feet, he finds that the flying is routine, even tedious. But because most of the controls are manual and the gap between flying too slow and flying too fast is only seven knots, the pilot must stay vigilant. The airplane is always at the edge of its envelope (see "In the Corner," p. 25). "A lot of people think we go up to altitude and shut the engine off and glide around for hours and hours," says Jim Barrilleaux, the only ER-2 pilot employed by NASA, "but it's still a large jet plane." All the same, the airplane is no lump of lead. If its single engine quits at altitude, it can glide for over an hour and cover more than 200 miles.

Before suiting up for the last of the TOGA COARE test flights, Bill Collette has a final meeting with the scientists whose instruments he'll be carrying. One of the main aims of the program is studying tropical storms, which affect the way the global atmosphere circulates. Until now, storms over remote tropical oceans have gone virtually unmeasured, except by relatively crude sensors on weather satellites. Several TOGA COARE instruments will make these measurements in far greater detail, but they will work indirectly, measuring heat radiating from Earth's surface directly below. The point is not to keep tabs on the Earth's heat but to use the heat as an indicator of rain. Rain absorbs infrared radiation, so fluctuations in the amount of that radiation reaching the instrument could be a nifty indicator of storms. Eventually, weather satellites could monitor tropical storms around the world with similar instrument packages. For now, the researchers need to fine-tune their instruments by looking at the radiation signature of different kinds of weather above different kinds of backgrounds.

"There's been a request to find some snow fields over the Sierras," says Jim Spinhirne of NASA, a scientist working on TOGA COARE.

"I'd like to see the bay," says a second scientist, referring to the San Francisco Bay.

"I'd like to see some rain."

"Okay, I'll try to find some weather," Collette says.

An hour before takeoff, Collette suits up with Walt Prouty's help and begins pre-breathing oxygen. In an ER-2's low-pressure cockpit, nitrogen dissolved in a pilot's blood would begin to bubble out of solution; his blood would, in effect, start to boil. Breathing pure oxygen helps purge the unwanted nitrogen. In an environment that's one-fifth

When the ER-2s operate from a remote site, they usually travel alone. At home at Moffett Field, California, they share the roost with an eclectic fleet, including a Lockheed C-141 (left). As the pre-launch frenzy builds, a technician dashes to replace a dead monitor (below). With a laminated checklist temporarily stowed against the canopy, 709 begins its roll to the launch runway (bottom).

normal atmospheric pressure, moreover, all gases in the body expand. Understandably, U-2 pilots never eat beans within 12 hours of a flight.

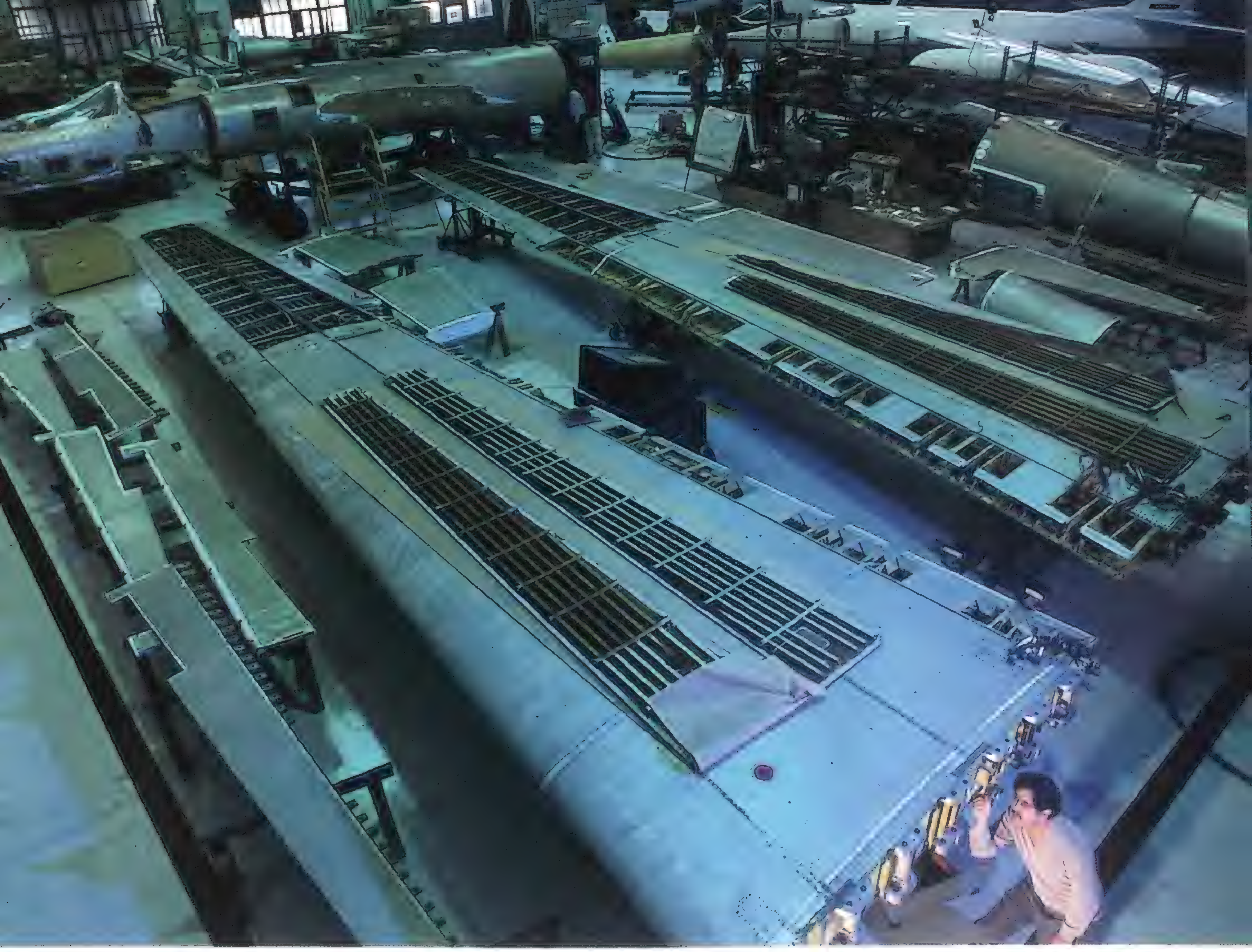
After a few minutes, Collette stalks out of the building to the pilot's van in clanking, bowlegged strides. His pressure suit's umbilical is connected to a battered oxygen unit that hisses and steams. On the way out to the airplane, Collette lies down in the van's recliner. So many tubes, nozzles, and wires trail from his suit that he looks like a patient in an intensive care unit.

In a sense, the image is an apt one. Readying an ER-2 for flight calls for a lot of support: not only oxygen and a pressure suit for the pilot, but a ground crew of at least nine, special jet fuel, and a long, hard runway. "It's quite an operation getting one of these things airborne," says Andy Roberts, who, like his colleagues, uses the term "launch" to describe the takeoff. "It's not quite as bad as a shuttle launch, but it's sure not as simple as getting a Boeing 747 into the air."

Finally, with the pilot squeezed into the cockpit and the canopy down, the airplane heads slowly down the taxiway. The engine is shrieking and the air is filled with the smell of kerosene. A crowd of TOGA COARE scientists has gathered at a chain link fence to watch, pointing cameras like excited tourists. Finally, Collette wiggles his wing flaps, slides the sun visor on his canopy to the overhead position, and moves the thrust lever forward. The airplane leaps ahead. After a few hundred feet, the fuel-laden wings finally begin to flex. A pair of stabilizing outrigger wheels called pogos drop from under the wings and clatter to the ground, and the crew scrambles onto the runway to retrieve them. A single plume of black smoke trails behind the airplane as it drills steeply up through the smog. It's out of sight in seconds.

By the time Collette reaches Oakland, 24 miles across the bay, he's already at 30,000 feet and climbing fast. The old U-2 had a comparable engine but was smaller and lighter. "It was a little hot rod," says ground crewman Richard Walden. "That thing just got up and sat on its tail." The old U-2 never actually climbed at a 45-degree angle, as some claimed, but it seemed to. Air Force pilot Jerry Hoyt once took a U-2 to 10,000 feet in 52 seconds, a rate of climb equal to an elevator rising 19 floors a second.

But pilots regard the airplane as a



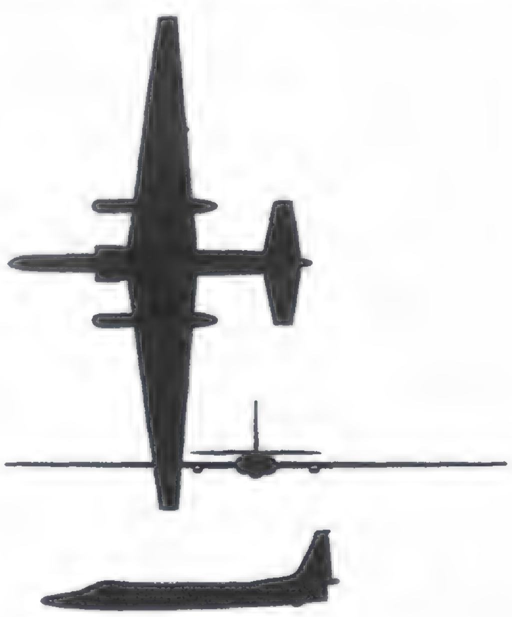
When an ER-2 comes in for maintenance, nothing is left to chance. Here, a disassembled airframe is being inspected by Lockheed technician Hector Martinez, who looks for cracks and fatigue in the fittings that attach the wing to the fuselage.

The Lockheed ER-2

The aircraft has been known as the Dragon Lady, the Deuce, the Angel, and, in intelligence circles, simply the Article.

At the request of the Air Force and Central Intelligence Agency, Kelly Johnson's famous Lockheed Skunkworks design shop developed and built the U-2, which first flew in August 1955. With cameras riding in their bellies, early U-2s were flown by civilian pilots employed by the CIA. On May 1, 1960, a Soviet missile downed a U-2 flown by Francis Gary Powers, embarrassing President Dwight D. Eisenhower and giving the Soviets a reason to halt a summit meeting. Today, the Air Force still operates the TR-1, a tactical reconnaissance version of the airplane, to gather radar imagery and electronic intelligence.

In the early 1980s, NASA began operating a special version designed for research in the earth sciences. Powered by a single Pratt & Whitney J75-P-13 engine and carrying more than a ton of instruments in an airframe weighing less than 18,000 pounds, the ER-2 can reach 78,000 feet.



workhorse, not a thrill machine. A U-2 squadron commander in Vietnam, Willie Horton remembers flying sorties from dawn to dusk in the 1960s, back and forth, his camera hunting for enemy activity. "I'd be on station for five hours and I'd see a [SR-]71 contrail above me, coming in from the China Sea toward Thailand," he says. "An hour later I'd see a contrail going the other way. I'd know that pretty soon that S.O.B. would be in a bar having a cold beer and telling stories and I'd still have five more hours up there. You can't imagine the feeling." But Horton loves the airplane, and

"Pogos"—outrigger wheels that drop off as soon as the ER-2 is airborne—are reinserted by the ground crew immediately after landing (above).

Particle samplers on the wingtip capture high-flying dust (above right). Volcanic dust and acids can etch exposed metals on the aircraft.

Once their research is approved, scientists like Robbie Hood of NASA Marshall (right) await their turn to fly experimental payloads.

now he loves being an environmentalist to boot.

Twenty-eight minutes after launch, Collette radios that he's at altitude. The scientists, meanwhile, have drifted off in small, tight clumps, chatting and joking nervously as they await 709's return. It's odd to think that a group of grown-ups could be so thrilled that their little boxes are hitching a seemingly uneventful two-hour ride in an airplane, but these people are as excited as four-year-olds the night before Christmas.

Ninety minutes later, 709 appears out of the smog to the southwest and blasts in low and loud. Collette makes a textbook landing—he holds the ER-2 a few feet off the runway as it decelerates before he allows the main gear to touch down. As soon as he taxis in, shuts down, and pops the canopy, researchers swarm over his plane like a Grand Prix pit crew. Quickly, they unscrew hatches and cart off boxes of data.

All but one of the instruments on board soon prove to have passed this final test flight. The exception is an enormously complicated Doppler radar sensor that fills most of the airplane's elongated nose. Its team will have to wait for another Christmas. When TOGA COARE goes operational next month, a huge optical camera—an instrument from a long waiting list—will be flying in 709's nose instead.

Back in the pilot's office, Collette waits for the postflight debriefing. A beach volleyball enthusiast, Collette looks and talks like a surfer, and he's more willing than the other pilots to talk about the visceral "kick in the butt" of flying the ER-2. "You get a rush of power flying a light airplane like this with a light fuel load," he says. He admits to managing a perfect landing today. An ER-2, he notes, takes some coaxing to put on the runway. "This plane does not like to descend," he says.

Despite the ER-2's quirks, the pilots are all intensely loyal to their aircraft, which may explain why they still want to fly it after a full career with U-2s in the Air Force. Lockheed pilot Doyle Krumrey, 53, has been flying the U-2 in one form or another for 25 years. Krumrey, who's perhaps a bit more tight-lipped and standoffish than the others, has his own reasons for putting up with the ER-2's unique mix of excitement and tedium: "I could double my pay flying a 747, but I don't want to work with all those other people," he says. "That's why I still fly a one-seater after all these years."

The ER-2 carries its 2,600-pound payload of sensors in the nose, equipment bay (behind the cockpit), and two wing pods.

FIGHTING FIRE FROM THE AIR

Part 1

The

Sometimes the best route to a fire is straight down.

Photographs by Randall Hyman

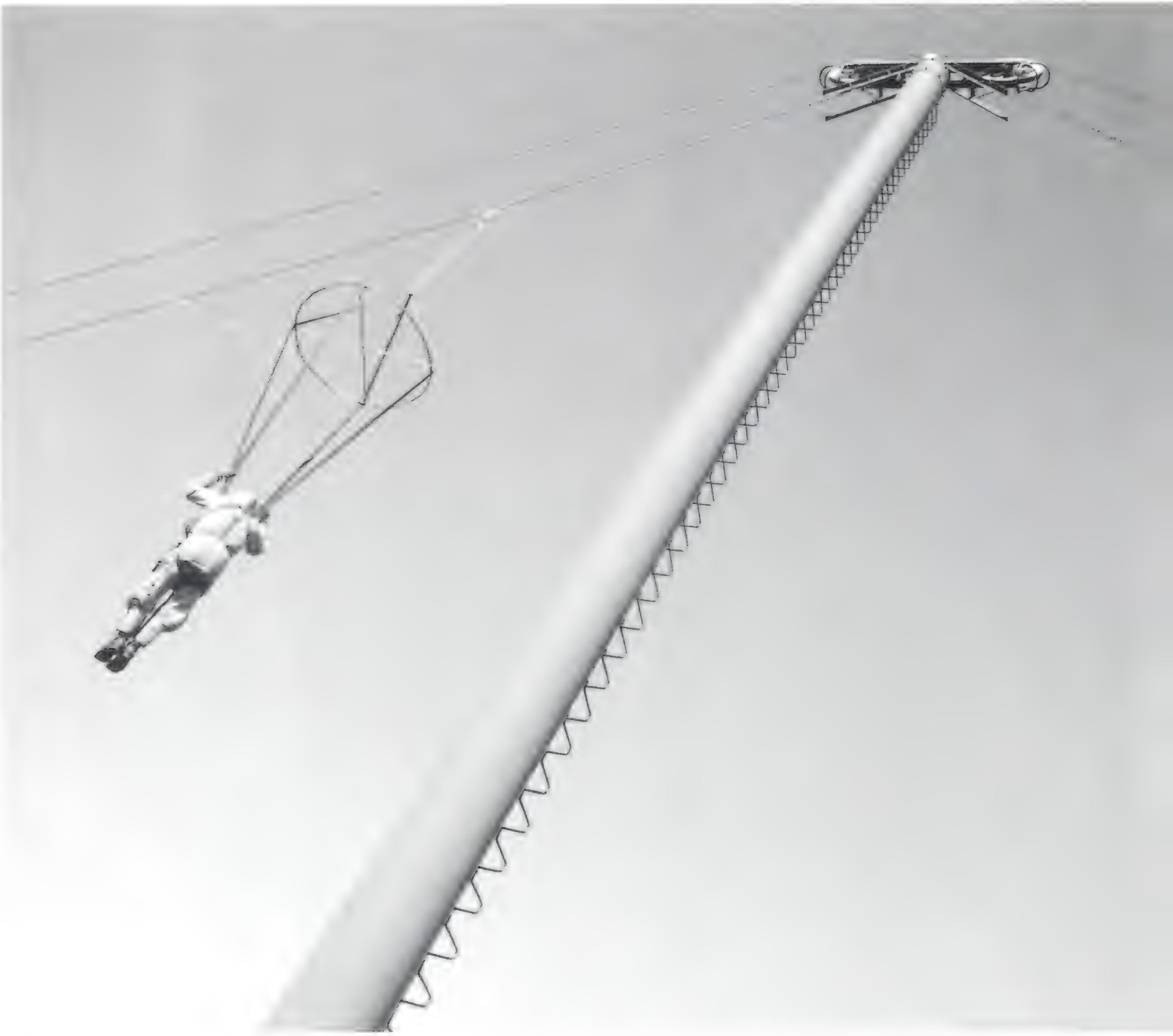
by Tom Harpole

Late every summer over the northern Rocky Mountains, thunderstorms hurl hundreds of lightning bolts. Some strike ground in thick timber where all the world is fuel. In a single afternoon, a storm's migration can leave a trail of a hundred spot fires. Many are extinguished in concurrent cloudbursts, but as the storm systems travel east, successive mountain ranges in their paths compress them, squeezing them almost dry. The farther east a mountain, the less rain it gets. By August all hell can break loose.

Every year Forest Service Region One loses an average of 130,600 acres to fire. Smokejumpers descend into rugged country to hold the loss in check.

KURT WILSON

Smokejumpers



To keep the backcountry from incinerating, the U.S. Forest Service employs a group of people expert in fighting fires and handling parachutes. They are hired to jump from airplanes onto fires in parched, remote forests. The smokejumpers of Forest Service Region One—comprising three bases in Montana and Idaho—owe their jobs to lightning, aridity, and the vast tracklessness of the Northern Rockies.

When the air raid siren bawls out over the tarmac at the Aerial Fire Depot in Missoula, Montana, pilot Tom Bohannan hustles for the base's DC-3 and has the right propeller turning within five minutes. Nearby in the smokejumpers' loft, parachute packers, people at sewing machines, desk jockeys, and a guy who looks like the janitor drop what they're doing and head for the ready room. The P.A. system hums on and buzzes out 16 names. The chosen stand at their wooden lockers suiting up in practiced haste to go parachute into a burning forest.

Twenty minutes later the DC-3 load of smokejumpers and their equipment nears a column of smoke in a section of Montana's Lolo National Forest that, by ground transportation and shoe leather, would take two days to reach. "Sometimes our response is so fast that we're flying the same ratty air that brought the lightning," Bohannan says. "The jumpers can handle 20-mph winds. But then we have to go down and make cargo drops from 200 feet." Bohannan is thoughtful and understated. "We get into some genuine mountain flying," he says.

Bohannan's passengers, 15 men and a woman, earned a seat on this airplane through a grueling selection process. The 70 smokejumpers who work fire seasons from Missoula rose to the top of a pool of 25,000 forest service firefighters. To apply for the job, a forest service employee must have two years of distinguished performance fighting fires and a letter of unreserved praise from a boss. The Missoula base, the oldest of nine smokejumping operations—all in western states—receives

400 applications each year. Perhaps two dozen get into a rookie camp so tough that half wash out.

By the time smokejumpers make it through camp, they can walk 15 miles with 110-pound packs stuffed full of parachute and reserve chute, jumpsuit, helmet, personal gear, food, and tools. They make these treks after days of the endless stoop labor that is firefighting. Many have stories of the three-day, 50-mile return hikes they call "paracamping." They speak unaffectedly of such labors with pioneer satisfaction.

It seems a countercultural calling. As a group, smokejumpers are hairier—and probably sport more earrings and tattoos—than a typical cross-section of public servants. During the fire season they wear a semblance of uniform intended to expedite the rush when the siren howls: $300 workboots, forest-green fireproof pants, and T-shirts that express predominantly liberal themes. In the smokejumpers' loft, "Young Republican" is a term of playful derision.

In June, when the fire season gets under way, the 20 smokejumpers who staff the base year-round are joined by another 50 people, many of whom arrange off-season lives to accommodate their summer commitment. Among those who showed up at the Missoula loft this year are schoolteachers, ski bums, loggers, a lawyer, a merchant sailor, bartenders, and a cruise ship hand. There are always a few souls who take the $10,000 it's possible to earn in a fire season and stretch it out over the rest of the year traveling. Of the 4,800 people who have worked as smokejumpers in this country since 1939, over

Smokejumpers spend more time with their parachutes on the ground than in the air: packing, repairing, or examining them for rips caused by snags on tree limbs (above). They don't need parachutes to practice landings, however. A simulator rides them to the ground at the same rate a parachute would, about 16 feet per second (above, left). Because most smokejumper injuries occur on landings, all the jumpers practice on the simulator at the beginning of a fire season. The jumpers have plenty of time to think about technique while they wait for a turn on the ride (left).

half used the work as a means of paying college tuition. It is an eclectic group that confounds expectations.

On the flight to the fire, the rear-facing smokejumpers alternately watch the spotter and the ground below and orient themselves with maps of the forest to which they are headed. Everett Weniger, a 37-year-old veteran of 12 seasons, looks for promising stretches of water. "When we fly to fires we see some real dramatic places that jumpers go back and find in the off-season. We see rivers we want to run. Some of us are climbers, some are campers. You couldn't sustain this work if you didn't have strong feelings about where you work and who you're working with." Weniger looks around the airplane at his colleagues. "You don't watch out you'll find yourself 40 years old and still wanting nothing more than this company, this work," he says.

Walt Smith, the spotter, stands in the hatchless door sizing up openings in the forest within about a quarter mile of the smoke. Over his helmet mike, Smith confers with pilot Bohannan. They assess the size and intensity of the burning and the position of the fire on the mountain. Sometimes Bohannan makes low passes "to see how flashy the fuels look and to get a good look at potential hazards," he explains.

Smith and Bohannan agree on a lumpy little hillside clearing and the DC-3 noses into the wind 1,500 feet above the jump spot. Directly above the spot Smith drops two weighted crepe paper streamers, which fall and drift as would a 175-pound jumper. On the next pass Smith drops two more streamers as far upwind of the spot as the first two drifted downwind. If the timing is right, the second set of streamers ride the wind into the drop zone and the exit point is fixed. Bohannan then begins flying an oblong orbit of left turns with the exit point at the finish line.

Through the open door of the DC-3, smokejumper Margarita Phillips smells the redolent blend of woodsmoke, turbine exhaust, and sweet, volatile conifer resins heated by the 98-degree day. Behind the wire-mesh face cage on her gouged yellow helmet she looks as resolute as a fencer poised to engage. With one hand gripping the overhead cable to which their parachute static lines are clipped, she and her partner stretch toward the door and assess the jump spot. Smith points and they crane to see. His succinct briefings are loud and portentous to those who land parachutes on mountainsides: "400 yards wind-drift...stumps in the brush patches...steep ridge...sunny side is windward..."

Suddenly breaking the urgency and volume of his instructions, Smith searches the jumpers' eyes to be sure he reads concentration and not a similar look known to the company as "the thousand-yard stare"—a composite expression of willingness overriding confusion. "Anybody can be having a day when they aren't focused," Smith says later. "I still do." At 45, he has been jumping for 21 years.

The Missoula Aerial Fire Depot's DC-3 was retrofitted with two Pratt & Whitney PT-6-67 turboprops in 1991. The airplane can carry 16 jumpers and their gear—about 6,000 pounds in all—to a fire (opposite).

Before a training exercise, one jumper does preflight stretches to prepare for the exertion of jumping and hiking (opposite, bottom). The depot's other aircraft, a Shorts C-23A Sherpa modified with windows, waits in the background.

Suiting up for a fire is a two-person job (below). Every jumper has a colleague check his equipment.

The airplane banks and levels into the home stretch and Smith drops to his hands and knees, pushes his head out the aft corner of the doorway into the prop wash, and watches for the exit point approaching directly underneath.

Phillips, 35, has jumped for five seasons and has trained her body to move purposefully with the 85 pounds of equipment she carries. "I weigh 210 going out the door, but I have to be vigorous," she says. "Exits are critical and set the tone of your next few days sometimes." She usually jumps second on a two-person "stick" because, without equipment, she is a lissome 125-pounder and doesn't fall as fast as her heavier colleagues, who could easily overtake and possibly collide with her.

Smith dramatically slaps the threshold, and, as he pulls his head back into the airplane, he tells Bohannan to reduce power. Phillips' partner sets his left foot where Smith slapped the door. A 100-mph wind tears by, inches from his face. Smith taps the jumper's left leg and he goes out silently. His static line thuds against the door's lower edge and sends a single faint shudder through the airplane as it jerks the parachute out of its pack. With no hesitation or change in expression, Phillips takes one step, grabs the outside edges of the doorway, and springs out into the slipstream.

Although they can't explain the physics involved, smokejumpers swear that sloppy exits will twist shroud lines. Un-

twisting sweeps a jumper's vision through dizzying panoramas for 20 seconds. Many more seconds are then needed to find the wind line—the prevailing current that smokejumpers must keep at their backs from the airplane to the ground—and relocate the jump spot.

Phillips' canopy pops from an elongate wad of fabric and shroud lines to form a round translucency that billows like a jellyfish. She looks around for her partner as she reaches up and grabs the control-line toggles, which, when pulled, make steering down the glide path possible. This is the moment she loves: the interlude before the drudgery.

The canopy ride lasts roughly 75 seconds, about one orbit of the jump ship. During the 1,500-foot descent a smokejumper can expect 1,200 feet of wind drift. While working their chutes toward the ground, smokejumpers call to each other to warn against collisions

BILL ALLRED

Part of the spotter's job is to tell the jumpers when to leave the airplane. Inside the Sherpa (top) the spotter signals a jumper with a tap on the shoulder. In the DC-3 the spotter kneels and taps the jumper's left leg. Jumper Walt Smith, who usually has the spotter's job, waits for the signal (above). Smokejumpers almost always exit the DC-3 in pairs (opposite), although over large jump spots three will leave in a group, or "stick."

over the small drop zones. Some curse as they run with the wind in a serpentine pattern of quartering curves that tighten near the spot. They watch for flattening smoke, which warns of surface turbulence, and they hope to land as airplanes do, making a last turn at about 300 feet above ground and a final approach into the wind to neutralize forward speed. The blunt toes of their boots serve as an open sight that makes their above-ground movement apparent. Landings vary.

"We had a real challenging jump into Rock Creek last year," says Gary Benavidez, the suave, trim superintendent of the Missoula base. "The air was squirrelly and turbulent. We were getting seriously thrashed in the plane. We kept circling and the spotter kept trying, but couldn't get a set of streamers to land in the bottom of this canyon." Benavidez pauses, unsmiling. "I asked my jump partner, Gino Bassette, 'What do you think?' Gino looked pale—half the guys had already lost their lunch—and he said, 'I think it's jumpable. Let's get the hell out of this plane.' " Benavidez says this jump tops his list of the 10 worst and continues the story. "The ride down took some work—lots of wind eddies pushing our canopies all over. I was trying to avoid a bunch of cottonwoods and committed to a level place. It was level all right. It was a stinking elk wallow. I went in up to my crotch. Softest landing ever, but when I finally got out I was carrying an extra 30 pounds of mud." Finally he allows himself a grin. "At least there wasn't an elk in there."

Even at her relatively light weight, Margarita Phillips can descend faster than 20 feet per second in the thin air at high elevations. The fast-rising, hazardous mountainside presents a ground rush few parachutists ever see. Her landing sounds hard-earned: the hollow smack of a body hitting the ground, followed by the rustle of gossamer fabrics settling.

The forest service's round parachute, the FS-12, has evolved through 50 years and 10 models. Although these chutes are slightly less maneuverable than square-rigged models, they have proved dependable under the complex demands of parachuting into turbulence and mountainsides. "We tried the squares, but you need a runway to land them and we don't often get big drop zones," says Paul Chamberlin, a bearded, content veteran of 200 fire jumps since 1971. Chamberlin has ridden three different forest service canopies. "These FS-12s open consistently on static lines and they hang up nicely in trees," he says.

Occasionally there are no good jump spots within several miles of a fire. Consequently, every year smokejumpers practice for and make numerous timber jumps. "Tree landings are a perfectly acceptable option and preferable to coming down into a bunch of rocks," says Chamberlin, "but they are one of

the biggest hazards we face. If you don't get your chute draped over the top of a tree, it can collapse and you fall that last 70 feet.

"There are funny stories about people falling unscathed from trees over a hundred feet tall. But it isn't funny when you're dangling up there by maybe just one shroud line and you begin falling incrementally, say 20 feet at a time. You might hit the side of a tall tree, snag something momentarily, and then fall. You think *This is it* and then you get caught up in a lower limb or a lower tree." To get from treetops to the ground, smokejumpers carry a 150-foot "letdown rope" coiled in a pocket they sew below the knees of their jumpsuits.

Before the DC-3 leaves the smoke, the loadmaster kicks out chute-equipped firepacks (food, fluids, and tools) from 200 feet while the flight crew ascertains the seriousness of any landing injuries and confirms radio frequencies. Smokejumpers go to work ignorant of how or when they will get home and relish that abandon. No forest service bus is parked nearby to haul them back to base.

When they do get back to the loft, smokejumpers spend their time repairing their parachutes and sewing their protective clothing, packs, and gear bags. It is not unusual to hear a roomful of men at sewing machines listening to the Grateful Dead while discussing the relative merits of landing in a young stand of Lodgepole pine over, say, big bull pine.

"I hate to deflate you, but we spend more time at sewing machines than we do fighting fires," says Jim Beck, a veteran jumper and master parachute rigger. His T-shirt asks: "What if schools had all the money they needed and the Air Force had to hold bake sales to buy bombers?" Beck's domain is a 4,200-square-foot room in which the cargo and personnel chutes are repaired and packed. The room is furnished with three rows of six 50-foot-long parachute packing tables and decorated with the insignia of other jump bases, cartoons, and homely aviation art. Inspecting and repacking a parachute takes about one hour. With 2,500 chutes to repack every season, the room is continuously populated by people straightening, folding, and tucking parachutes into packs the size of grocery bags. Parachute packing is dead serious work, but the loft isn't a quiet place.

"Jumpers are good b.s.'ers—don't quote me—they're exceptionally energetic people," says Beck. "They enjoy each other and jack each other up. When the seasonal people show up, the stories about travel are always outlandish." Most of the stories in the loft, however, are about smokejumping.

The best-known smokejumper story in Montana became nationally known last year when the University of Chicago Press brought out *Young Men and Fire*, a book by Norman Maclean about the occupation's most horrific tragedy. Maclean tells the story of 12 smokejumpers and a wilderness guard who died on August 5, 1949, when they were overtaken by a fire in Mann Gulch on the Missouri river 25 miles north of Helena, Montana. The average age of those who died was 22.

Mann Gulch is a steep, stunted canyon, little more than a mile-long geologic chimney. Despite local turbulence, all the smokejumpers landed safely near the top of the gulch. Clad in cotton shirts and dungarees, they headed down carrying heavy hand tools. Half a dozen spot fires at the bottom of the gulch braided into a dervish of upslope winds that hounded them back up a fuel-loaded incline as steep as they get in the Rockies. Near the head of the gulch but obviously losing the race, the foreman stopped, lit an escape fire in dried grass, and entered the small burn. It was an inspired tactic intended to deprive the approaching monster of fuel, but that was incomprehensible to the stampeded young men. They refused to join him. The main fire hit them seconds later.

"Mann Gulch has happened over and over again. But it never happened to jumpers again. No jumpers have burned up since," says Wayne Williams, a smokejumper with a prominent wedge of jaw who has made 130 fire jumps and is the unofficial historian of the organization. "That's due mostly to the lessons never forgotten about Mann Gulch," he says quietly.

Some of the lessons are codified. From this and other fire fatalities came the 10 "standard orders" of wildland

firefighting. Laird Robinson, a lanky, heedful woodsman who jumped fires for 13 years, traces one order in particular to Mann Gulch. "Know what your fire is doing at all times," he recites. Robinson led Norman Maclean on four trips back into Mann Gulch to investigate the fire, and he speaks regretfully of young men having to drop their firefighting tools. His own smokejumping career was shortened when he landed in high surface winds and broke his back against a downed Lodgepole pine. By the next fire season he had convinced himself he was healed. He jumped again, reinjured his back, and faced an adamant doctor who told him the next jump would probably paralyze him. Robinson's ethos is in the Mann Gulch story and is the attribute most common to the smokejumpers' successes and tragedies.

"On a fire you have this powerful mix of human behavior and fire behavior," Wayne Williams explains. He moves somewhat stooped, perhaps from 20 seasons digging fire lines. He is an articulate Visitor's Center guide and speaks learnedly of smokejumper history. "Each fire has its own personality. Some are monsters that gobble up the country by the square mile. Some are tameable. You work with one boot in the black and herd the fire where you want by robbing the fuel from its edges. Smokejumpers also have very strong personalities—mostly real stubborn people who react better the more a fire throws at them. We hardly ever lose a fire."

Once they're on the ground the smokejumpers' task is the same as that of all forest firefighters: remove potential fuel ahead of the fire—dig, saw, hack, and drag dry stuff away. The main weapon against the flames is a Pulaski, a half-axe, half grub-hoe made for chopping and trenching.

"I think we all assume that every fire jump means a straight 24-hour shift," says Williams. "We can go longer than that if necessary. You're just up there 'chinking fire line' mindlessly for hours; all you know is sweat, thirst, and that *chink chink* sound of your Pulaski biting into the dirt. I've seen fire lines when 20 jumpers have been digging for 16 hours and 14 of them are puking, but they are still digging like army ants."

The respect this stamina has fostered in the forest service may be the reason the occupation of smokejumping has lasted for more than 50 years. Smokejumpers can also go into spots where no helicopter can land, and, unlike chemical retardant, they can actually extinguish rather than merely slow a fire.

Despite its hazards, smokejumping appears to be no more dangerous than other means of attack. In more than 300,000 jumps made since the program began, three jumpers have died in parachute-related accidents. A serious injury occurs every 100 jumps. In 1992, an atypically bad year, 80 Missoula jumpers made 1,607 fire and practice jumps and incurred 24 lost-time injuries.

Smokejumpers speak of trauma with the detachment of paramedics. Conversations about injuries usually turn into stories of wrecks past, like the one about Floyd Whitaker's double malfunction. Whitaker, a 200-pounder, had, as they say, "a big motor." Every landing crumpled him but he always got up. On a routine exit into the thin air over the Gila National Forest in New Mexico, his shroud lines not only twisted but got looped over his canopy, causing it to "streamer." Whitaker spent a few seconds trying to get his main chute untangled, then at about 500 feet he pulled his reserve, which got wrapped around his main. His jump partner on that stick, Jim Linville, watched Whitaker fall for 15 seconds struggling with his equipment. "He augered into the timber at about 80 miles per hour," Linville says. "He was a goner."

Jumpers on the ground watched him fall and hesitated to cross the ridge to see what they assumed would be his remains. What they found was a mummy-like object downslope; as he rolled down the steep hill, Whitaker had been wrapped in his two chutes. The crew reluctantly cut away shroud lines and canopy. Whitaker remembers coming to in his cocoon hearing familiar voices and realizing, then, that he wasn't in heaven. When the canopy was cut away from his face he blinked, bummed a cigarette, and limped back up the sidehill on a badly sprained ankle to await a helicopter.

How smokejumpers deal with fear is one of the questions Wayne Williams most often fields at the Visitor's Center. "Complex question," he replies. "None of us believe we'll be the one to get it. That doesn't mean we're putting bad joss on the others, either. We wouldn't be here if we didn't feel bulletproof around each other." Smokejumpers are canny and accomplished in the presence of disaster, so the possibility of tragedy is unpersuasive to them. A tentative life on the periphery would be, to them, the real tragedy.

The only parachutists who aim for trees, smokejumpers must practice techniques for getting down (left).

Concrete crosses mark the spots where 13 bodies were found after the infamous Mann Gulch fire in 1949.

PHIL SCHOFIELD

Beyond Aeronautics

Guy Pignolet, Youth and Education Engineer, CNES; Co-Chairman, Education Committee, International Astronautical Federation

For space exploration, we have leaned too heavily on the aeronautical brilliance that got us started.

A few months ago, at the end of a long day in my office at the Centre National d'Etudes Spatiales (CNES), I was impatient to get to my flat in the St.-Germain-des-Prés district of Paris. It's in an old house on a small street. The building itself is about a hundred years old, and the basement dates back to some time in the 13th century. A dozen years ago, the owner managed to squeeze a lift into the center of the stairwell. It's probably the smallest and slowest elevator in Paris. Out of curiosity I counted the seconds to the fourth floor: *28, 29, 30*...

As I was pushing open the door of the elevator and looking for my keys, it occurred to me that 30 seconds is about 1/30th of the time needed to go to orbit. If I had a flat in a low orbit around Earth, I could be home in 15 minutes. Of course I'd need another elevator.

I then wondered why we who work in the realm of space activities never think of space elevators but always of space*craft,* the semantic offshoot of "aircraft"? The reason is that we have developed the habit of thinking about space as *aero*space. Because of the origins of the space era, we subconsciously yoke the separate disciplines of aeronautics and space travel. But the hidden hyphen in the word "aerospace" is a dangerous mind trap, and to gain the freedom to challenge space on its own terms, we ought to take a pair of scissors and perform some overdue surgery.

At this point in its development, we can view the field of space exploration as the promising child of aeronautics, which was about to mature and live on its own when it ran headlong into a difficult adolescence. The Russians have successfully run the Salyut and Mir space stations, but they could not take the logical next steps, constructing a permanent outpost on the moon. The Europeans have mastered the Ariane launcher, but they have made no progress toward the dream of a European moon program. In the United States the space station has stalled, and only the space shuttle remains of Wernher von Braun's ambitious program to move humankind outward. Those of us who have worked in the field look around and, like baffled parents, ask ourselves *Where did we go wrong?*

Paradoxically, we have leaned too heavily on the aeronautical brilliance that got us started. Following the dazzling successes of airplane manufacturers, we have limited our ideas to transportation. The project that has done more than any other to keep the dream alive is the U.S. space shuttle, a winged spacecraft and an engineering marvel. But the shuttle has so deeply anchored space developments in their aeronautical origins that it has kept the dream alive at the expense of reality. The reality is that there are no plans for large space operations with benefits to offset the cost of transportation. Instead of working toward those objectives, the Europeans were seduced by the achievement of the shuttle and the fallacy of winged craft into undertaking the ill-fated Hermes project, a rocket-launched spaceplane. And the Russians, forgetting that they already had the world's best space transportation system, built the Buran shuttle. Until recently the U.S. aerospace industry pushed the National Aerospace Plane as the ultimate achievement in space transportation. Even with the financial crises of the past decade, these countries had money enough to build a moon base, develop efficient electric propulsion in space, and build large stations as staging locations from which to move outward. But much of that money was misdirected to the projects just named because of the attachment to wings and joysticks. Should the shuttle stop its operations? Of course not. But neither should new programs follow its developmental path.

When the question changes from *Where did we go wrong?* to *What do we do now?* the answer must be *Sever the umbilical cord between aero and space.* For the aero-minded, space is somewhere beyond the blue of the atmosphere, a place you fly out to. For the space-minded, Earth is the bottom of a gravity well, and you try in some way to lift

If space enterprise is to mature, it must take off on its own.

yourself out of it. With this point of view comes the realization that you need no wings to escape the surface of the planet and no wings to return. An Apollo or Soyuz capsule is not a prefiguration of a spaceplane cockpit but rather a simple elevator cabin. After a 20-minute ride you leave it for weeks or months, and when you return, you just need atmospheric braking down to the ground. With small thruster corrections, a capsule can land within a few hundred meters of its target. Those who argue that a shuttle is reusable whereas the earlier capsules were not lose sight of the fact that the most sensitive parts of the winged spacecraft—the engines—still need to be regularly replaced, not to mention the tanks and solid boosters.

It is not easy for airmen to think about giant space power systems, interplanetary space tugs, or moon manufacturing. But to those who have already converted to the space mindset, such thoughts are familiar. The challenge now is to make such thinking the norm instead of the exception.

The most effective tool for freeing space of its dependency on aeronautics is formal education. But in today's aerospace engineering schools in Europe and the United States, the curriculum is driven by the aeronautical environment. Only by electing upper-level and graduate courses can students specialize in space technology. How can these students learn enough about space medicine, communications, or astronomy? If their primary training were in general astronautics, with later specializations in Earth observation, radio communications, and even aeronautics, they would be better prepared to conceptualize genuinely integrated space systems.

For this reason the establishment of the International Space University in Strasbourg, France, seems to be the most important step so far taken toward an independent discipline of space science and technology. The ISU curriculum begins with the assumption that its disciplines will be practiced *in* space, not getting *to* space. The ISU, however, should not remain the only choice for students.

The conversion should also take place in industry. In France Arianespace has been the first company to position itself as a simple carrier, letting its client corporations find their own niches in space commerce. Its founders realized that the essential part of space technology—what some refer to as merely "applications"—is the hardware that works in space. So far, only the communications industry has accepted the challenge to design its own space systems. The major utilities should be the next to enter the space arena.

A clear example of the failure of aerospace companies to solve space problems occurred in the late 1970s, when engineering visionary Peter Glaser proposed orbiting satellites to provide solar energy for Earth. Millions of dollars were spent paying hundreds of aerospace specialists to assess the practicality of the idea. The specialists determined that too many shuttle flights would be necessary to ferry from Earth to geostationary orbit the thousands of tons of materials required. After the final report, the Space Studies Institute of Princeton asked why a possibly more economical option had not been considered—that of constructing mining operations on and launching materials from the moon. Only after SSI challenged their results did the aerospace engineers acknowledge that the lunar option had never occurred to them.

One generation after the dawn of the space era, keeping "aero" attached to "space" restrains us from taking bold new steps in Earth orbit and beyond. Space will not fulfill its commercial or scientific promise until the next generation's space professionals can envision not only the excitement of leaving Earth but also the challenge of managing its global environment with the resources of the solar system.

The opinions expressed in this essay do not necessarily represent the official views of CNES.

The essential part of space technology—what some call merely "applications"—is not the means of travel to space but the hardware that works in space.

Rendezvous in Space

It's risky. It requires uncompromising precision. And without it, space exploration would be nowhere.

by James E. Oberg
Paintings by Pat Rawlings/SAIC
Drawings by Carter Emmart

Things had gotten really confused aboard the shuttle *Endeavour* on its mission to rescue the Intelsat VI satellite. Halfway through the third and last rendezvous sequence and already concerned about low fuel levels and an uncooperative target, the crew was now facing communications and navigation problems. Then the aiming software in the shuttle's onboard computer started behaving erratically, and for the first time in NASA's long history of orbital rendezvous, the astronauts and mission control had to call a time-out. The shuttle halted its approach to the Intelsat, and everyone took a deep breath.

"It was a real flail," copilot Kevin Chilton recalls of the May 1992 mission. Chilton had descended from the *Endeavour*'s flight deck to consult with Rick Hieb, who had been a rendezvous expert at mission control before becoming an astronaut. Now Hieb was in the airlock with two colleagues, waiting to go outside and grab the satellite. Anything Hieb said would be relayed down to Earth through his spacesuit radio, so even though the two astronauts were standing just a few feet from each other, there was no way for them to engage in a private conversation.

"I made up a three-by-five card," Chilton says, "and then I knocked on the airlock window." One side of the card said "GET RICK." After some struggling and squirming, Hieb appeared upside down in the window. Chilton turned the card over and showed him two questions: "1. WHAT'S GOING ON? 2. HOW ARE WE DOING?"

Hieb, who had been following the situation over his suit radio, grinned and pantomimed rapidly. He raised a finger—*One*—and shrugged his shoulders—*Haven't any idea*. He raised two fingers, then gave a vigorous thumbs up—*You're doing fine*. Encouraged if not enlightened, Chilton returned to the flight deck, and the rest is history. Hieb later recalled that at that moment he realized how weird the mission had become, but his confidence was genuine and, as it turned out, justified.

After the brief delay, mission commander Dan Brandenstein flew *Endeavour* in for its third and final rendezvous with the Intelsat. As he later described it, any successful rendezvous engenders "a mixture of exaltation and relief" in the crew, and this one was no exception. Hieb, together with fellow spacewalkers Pierre Thuot and Tom Akers, made the grab and saved the mission.

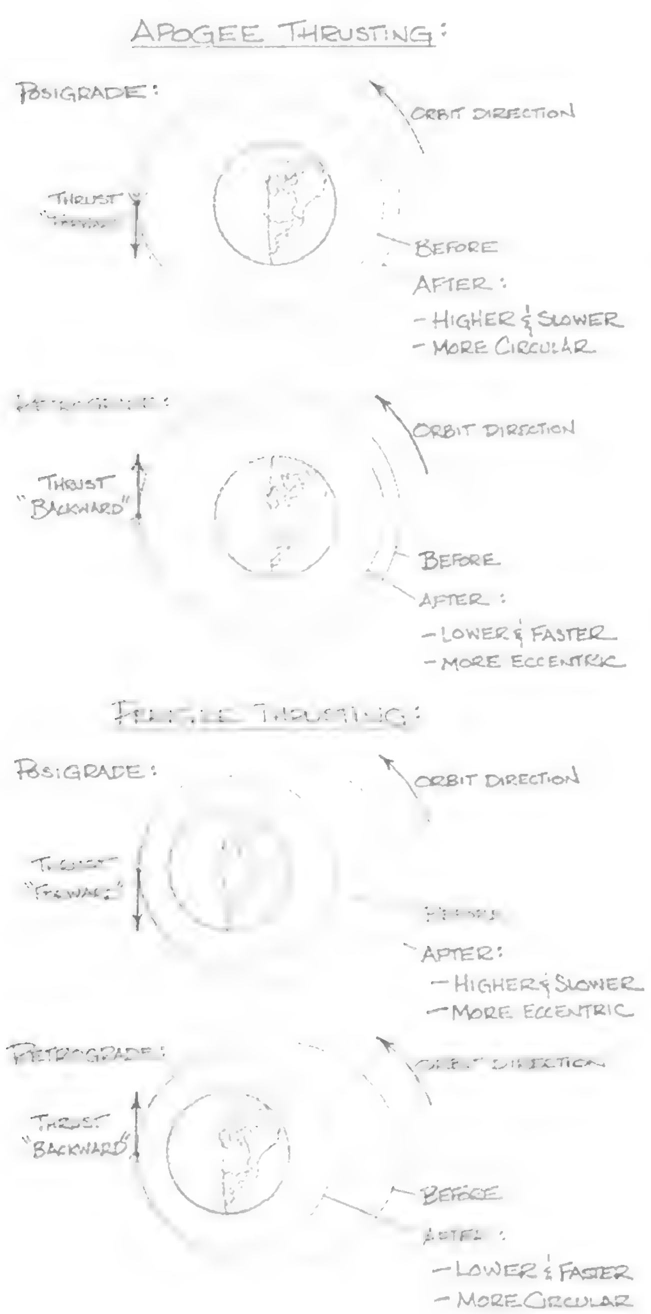
The ability to rendezvous with an object in orbit had made this rescue mission possible, just as over the previous 30 years orbital rendezvous had made

Operations in low Earth orbit have been the keystone of both U.S. and Russian manned space programs. A planned 1995 space shuttle rendezvous with the Russian Mir space station, depicted here, will demand a precisely timed launch and all NASA's rendezvous know-how.

possible the Apollo lunar landings, the Skylab space station missions, the Apollo-Soyuz linkup, and a series of other space shuttle repairs and retrievals of orbiting satellites. And every one of those missions had followed much the same sequence of development, from the original mathematical planning to the final execution. As a flight controller with many mission control teams, I've had a front-row view of both the planning and the execution of some challenging rendezvous missions.

All spaceflight is dangerous, but flying a fragile vehicle up close to another object involves a higher level of peril. More things must go right, and with precise timing, than at nearly any other phase of a mission, yet NASA has made orbital rendezvous look almost routine.

It didn't start out that way. In 1965, manned spaceflight was new, and orbital rendezvous was still a dream. But the success of the Apollo program depended on an untried technique called lunar orbit rendezvous: the command module and all the equipment needed for return to Earth would orbit the moon while a lander descended to its surface. After their explorations, the astronauts would return to orbit around the moon, where they had to dock with the command module. If they failed to link up they would die. Theory said the technique should work, but proving it in space was one of the key purposes of the 10-flight Gemini program during 1965 and '66.

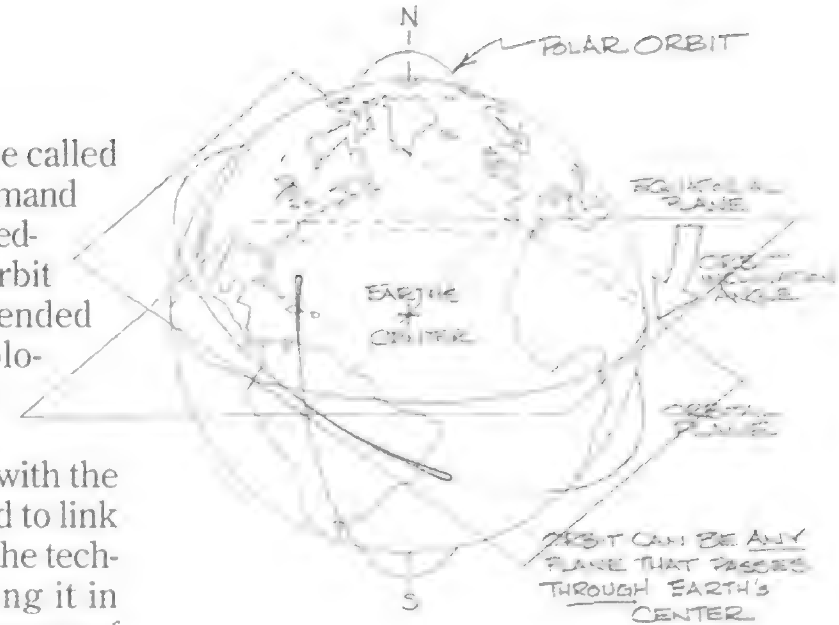


Analysts knew that successful orbital rendezvous required several conditions. First, the chaser vehicle had to be placed in nearly the same orbital plane as the target. Then it had to overtake the target at a rate that would place the crew in sunlight during final maneuvers. The crew had to use onboard sensors to acquire the target because ground tracking was not precise enough close in. And finally, the chaser had to approach the target reasonably slowly in order to make physical contact.

In orbit, height and speed are coupled. The higher the orbit, the slower the spacecraft will orbit. When thrust is added in the direction of its orbit, a spacecraft gains height and loses speed—the opposite of what might be expected. The orbit's shape—circular or eccentric—is determined by the addition of thrust at the apogee (the highest point in the orbit) or perigee (the lowest point).

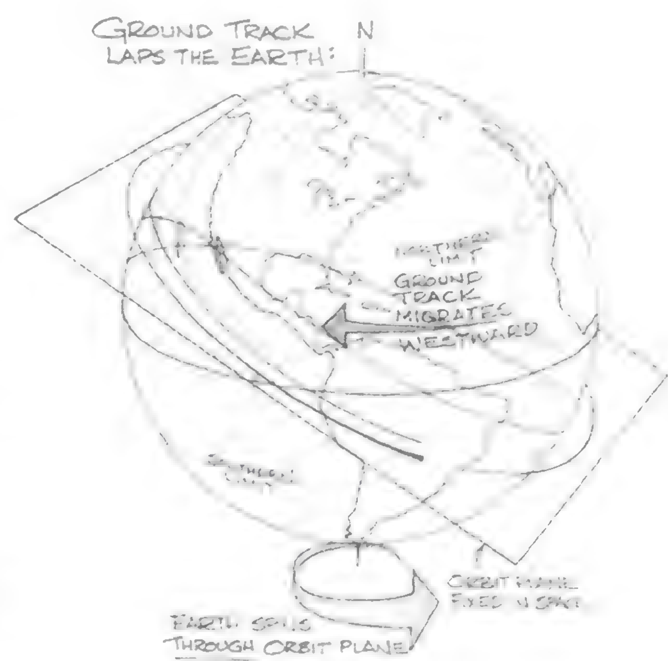
Before the first spaceflights, planners were concerned about how to place the chaser spacecraft into an orbit close enough to the target's orbital plane. In four minutes, Earth rotates through one degree in space. Two spacecraft launched from the same point and in the same direction at an interval of four minutes would enter orbits one degree apart. That may sound small, but once in orbit, correcting that much planar misalignment would require more fuel than a spacecraft normally carries for its entire mission. So the proper plane has to be achieved by ensuring precise timing and direction during launch.

Launching a rocket due east gains maximum advantage from Earth's spin, and because the geometric center of all orbits is the center of Earth, the re-



sulting orbit has an inclination to the equator that equals the latitude of the launch site. For example, a launch due east from Cape Canaveral in Florida would have an inclination of a little more than 28 degrees. (If you have trouble visualizing this, use a sheet of paper to represent the orbital plane and cut out a hole large enough to accommodate a globe; after "launch" rotate the globe.) Earth's rotation carries the launch site past the orbit's northernmost arc just once each day. Gemini's targets were put into orbits with inclinations slightly above the launch site latitude, so the launch site was fairly close to the target plane for almost two hours.

A planar window open this long is crucial because space launches don't



always get off exactly on time. More important, the target's relative position isn't always right for starting the chase. If the target is too far ahead, the chaser can't catch up at the right time; if it is too close, the chaser overtakes it too soon. Only a brief arc in the target's 90-minute orbit offers the chaser any hope

of catching up successfully. This short segment is called the phase window of the mission. It is determined by the target's altitude, the initial altitude of the chaser, and the allowable mission duration. Early Gemini missions had limited endurance, so a rendezvous usually had to be made on the first or second day. And when the first rendezvous missions were designed, the phase window was often open only a few minutes, although it reopened with every orbit.

Both the planar window and the phase window must be open for a successful rendezvous—one without the other is useless. But if both the planar window and the phase window are short, the chances of their coinciding during a single target orbit are pretty slim. A technique called yaw steering provides some leeway in the opening of the planar window. If at the moment of liftoff the target's orbital plane is a few miles to the left or right of the chaser's ascent path, the chaser can gently turn to the left or right during the nine-minute climb into space and slip into the proper plane even if the initial geometry isn't exactly right.

Yaw steering was invented by Gemini planners. Although it required that payload be sacrificed for fuel, yaw steering provided a planar window that was open longer than a complete target revolution. The spacecraft could wait on the ground while the target advanced through its orbit until it moved into the proper phase window. Some additional leeway was provided by allowing for a lower chasing orbit in the event of a delay, so the target's extra lead could be overcome by the chaser's faster approach. That's how Gemini 6 completed its pioneering rendezvous with Gemini 7 on December 15, 1965, and that's the way space shuttles will dock with a future space station. Nature made the laws of motion, Newton codified them, and NASA rendezvous planners learned how to use them.

Planning a rendezvous was even more difficult for the Soviets. Their spacecraft, which are launched from Baikonur, can't be aimed due east because they'd be over the Chinese border within minutes. Their rockets have to follow a northeasterly path, so the satellites' orbital inclination is higher than the launch site's latitude. The launch site rotates through the target's orbital plane very quickly, and the planar launch window can't be stretched beyond a few minutes. Soviet space stations also orbited at low altitude. That meant the phase window had very little leeway because a chaser couldn't fly much lower to play catch-up. Finally, the endurance of Soviet manned spacecraft was limited, which meant they had just two days to link up before they had to return.

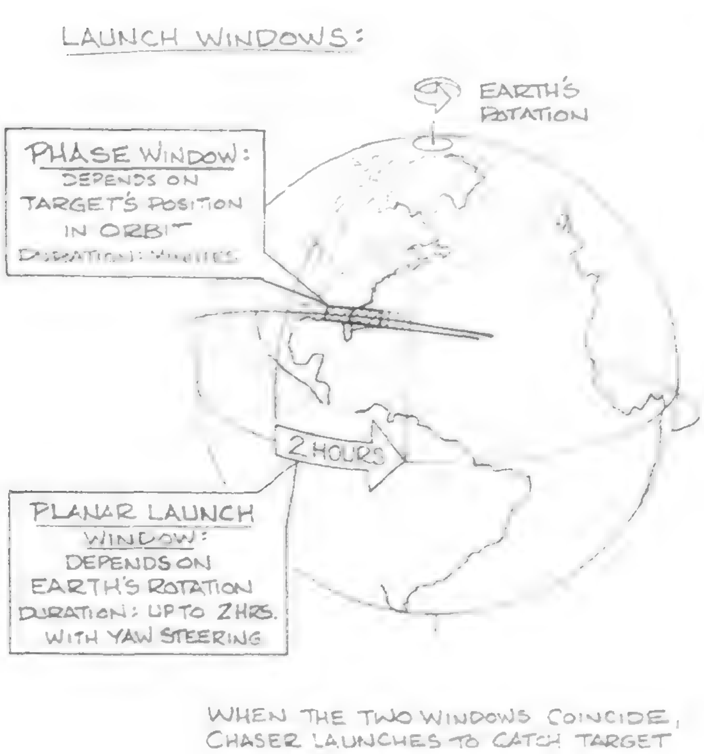
The Soviets chose to adjust the orbit of the target satellite in order to shift the short phase window to coincide with the short planar window. They used small rockets to adjust the height (and therefore the time for a single circuit) of the target's orbit. These orbital maneuvers could be observed by Westerners many days in advance, and during the 1970s and 1980s crew visits to the Salyut space stations, which were never announced until after launch, could be predicted as if by magic.

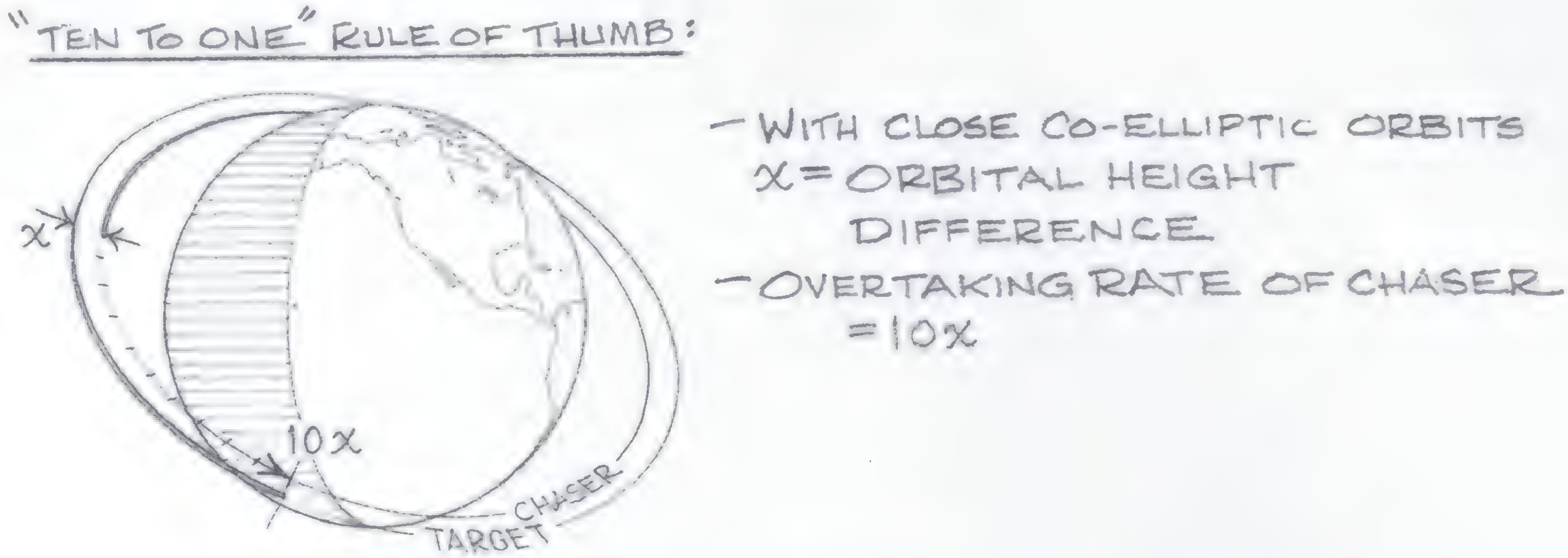
The space shuttle will face two special problems during its planned orbital rendezvous with Russia's Mir space station. The launch pad at Kennedy Space Center in Florida rotates quickly through Mir's highly inclined orbital plane, so the launch window is open only a few minutes. If the countdown is delayed much beyond that relatively tiny interval, the launch will have to be rescheduled. As for the slow rate that the shuttle will have to assume to "phase" with Mir during its overtaking period due to Mir's relatively low orbit, the shuttle will handle this by al-

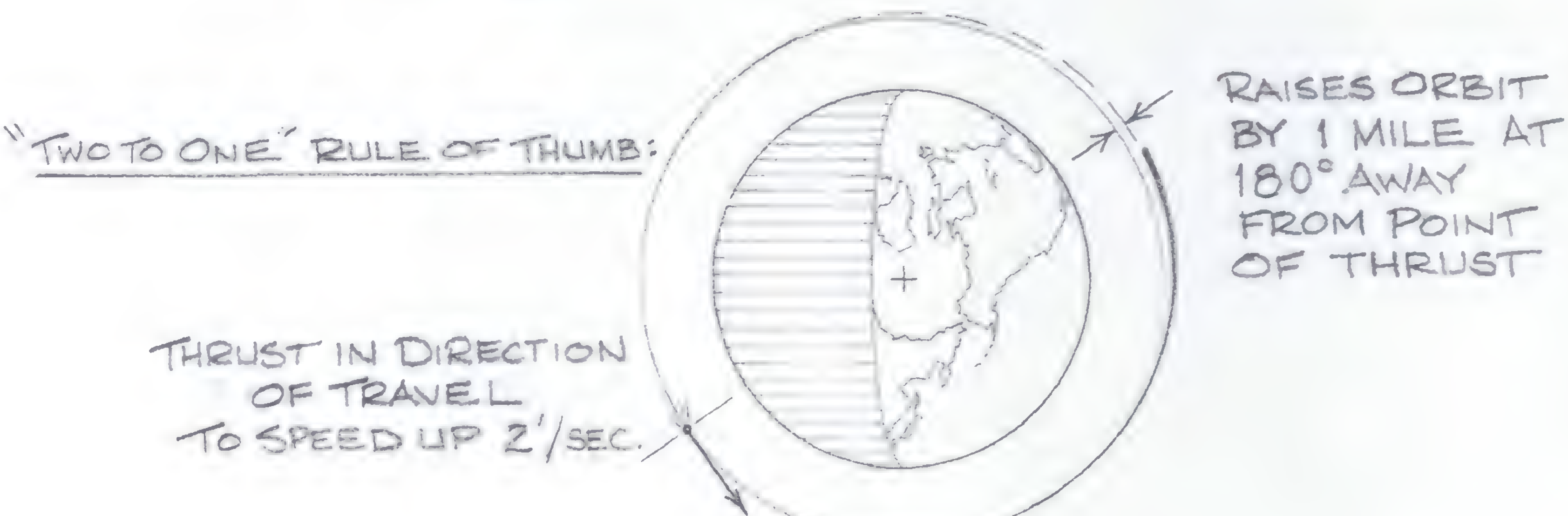
lotting a generous period of up to six days to complete the rendezvous.

But launching on time is only the beginning of the problem of rendezvous. Once in orbit, the task of catching the target has proved one of the most difficult for astronauts to master. Because the so-called "orbital mechanics effects" are counter-intuitive, a simple maneuver during pursuit of a target spacecraft can produce the exact opposite of what the pilot is trying to achieve. Astronaut Buzz Aldrin, who was a key player in the development of rendezvous procedures, once wrote, "The instincts an astronaut had that kept him alive flying jet fighters could easily betray him in space." Unwarned, astronauts on the first rendezvous attempt, made during Gemini 4, tried to fly their spacecraft like a jet interceptor, approaching the target from above and behind. But all that forward thrust only boosted their spacecraft into a higher, slower orbit, and they fell hopelessly behind.

The improper position behind and above the target became known as the "McDivitt Quadrant," after the frustrated Gemini 4 pilot, James A. McDivitt, who showed it wouldn't work. Four years later, on Apollo 9, a wiser and better-trained McDivitt became the first man to bet his life on a rendezvous when he separated the manned lunar lander (which was incapable of returning to Earth by itself) from the Apollo com-







Rules of Thumb

Getting into the proper orbital plane is only the first of two major windows that a rendezvous mission must pass through. The second is called the phase window, and it is based upon the phase angle, a term borrowed from electrical engineering (where it has a different meaning) and defined as the angular separation between an orbiting target and its chaser spacecraft. The calculations to determine the phase window can be roughly estimated.

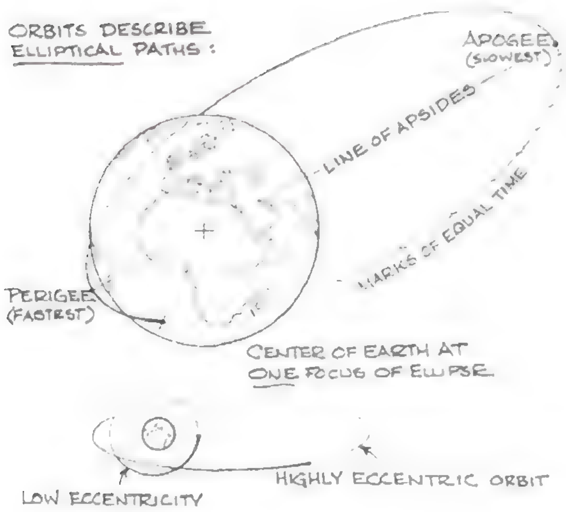
The mathematics of two-body motion is complex but has been well understood since the time of Kepler and Newton. Modern computers can project a satellite's motion to anticipate necessary maneuvers. Over the past three decades, however, astronauts and flight controllers have developed their own rough "back of the envelope" tricks for getting fast estimates of orbital motion before the computers can spit out their high-precision results. Starting from simple assumptions (orbits already in the same plane and nearly circular) makes the mathematics manageable.

The "ten-to-one" rule states that the separation rate of two nearby satellites will be ten times their altitude separation per revolution. For example, two objects averaging 10 miles apart in altitude will drift apart 100 miles per revolution.

The "two-to-one" rule states that to raise one end of an orbit by one mile requires a burn of about two feet per second at the opposite side. To raise the apogee 10 miles would require an impulse of about 20 feet per second, timed to occur 180 degrees ahead of the desired raise point.

Spaceflight operators memorize other standard orbital maneuvers: for example, the relative motion resulting from a chaser performing a one-foot-per-second burn in the forward direction creates a higher, slower orbit, which results in falling behind about three miles per revolution. Burns in other directions create different kinds of motion.

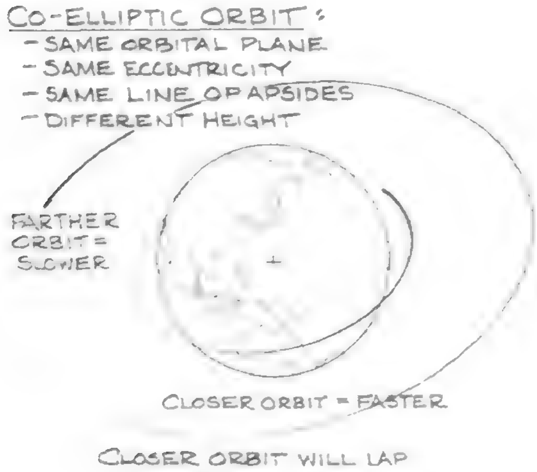
These simple rules, often so contrary to Earthside common sense, show how the chaser-target phase angle is controlled by the chaser's raising or lowering its own orbit. For a target 180 miles up, a chaser 150 miles up will overtake it by 300 (10 times 30) miles per revolution. The entire orbit is a little longer than the circumference of Earth, or roughly 25,000 miles, so a complete circuit in which the chaser "laps" the target would take about 80 revolutions, or five days.



mand module for the first time and then flawlessly rejoined the two.

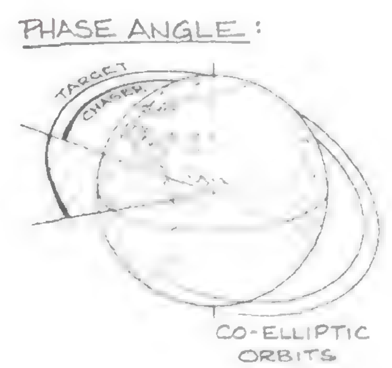
The question facing Gemini rendezvous designers was how to design the catchup maneuvers and manage the relative motion during the chase and approach. Initial strategies involved placing the chaser into an elliptical orbit with its apogee as high as the target satellite's circular orbit. Then, at successive apogees, small rocket burns would raise the chaser's perigee, lengthen its orbital period, and thereby reduce the closing rate. The last revolution before rendezvous would be from only several miles behind the target, so the relative speeds between target and chaser would be quite low.

But there were problems with this strategy. The final rendezvous would have to occur halfway around the world from the original launch position, and the lighting and tracking conditions there might not be acceptable. The navigation and the rocket burns would always be a little sloppy (engineers call these errors "dispersions"), and the final approach vector would require the spacecraft's navigation system and computer to operate perfectly. What looked feasible in theory wasn't realistic on an



actual spaceflight with real hardware.

Several teams of young engineers—at NASA in Houston, at the Gemini office of McDonnell Douglas in St. Louis, and at the Massachusetts Institute of Technology's Draper Laboratory—worked on the rendezvous maneuver strategy in the early 1960s. After considerable research and debate, they developed a plan employing a lower parking orbit below the target. To simplify the calculations of relative motion, the plan called for an initial overtaking orbit with a constant altitude difference, or in geometric terms, a "co-elliptic orbit." Once the target, orbiting ahead of



and above the chaser, achieved a certain elevation angle above the horizon, the astronauts thrusted directly toward it, adding velocity in increments calculated from the target's observed angular rate across the sky. In less than an hour, they would be right next to it.

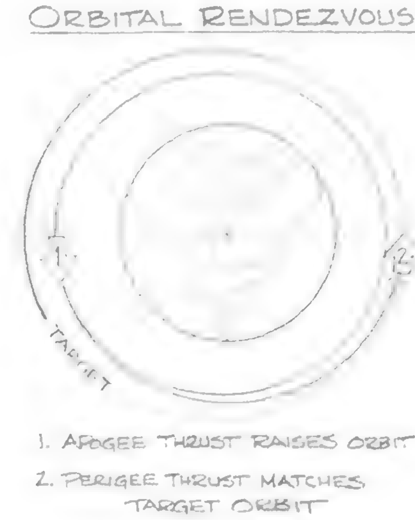
The new approach had several payoffs. For the final approach the pilot had only to manually control lateral deviations and brake down to prescribed speeds at prescribed ranges; orbital mechanics would take care of all the rest. Best of all for real-world planners, says Paul Kramer, a member of the NASA team, the strategy was "highly successful for contingency situations: radar failures, platform failures, and control-systems-degraded modes."

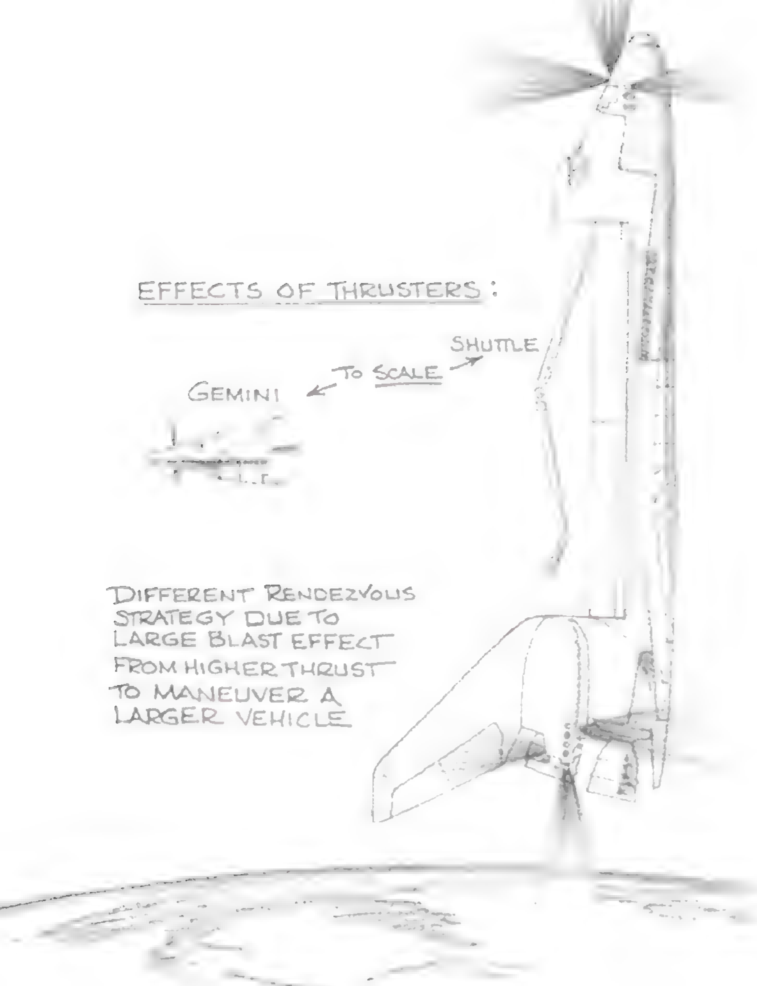
And Gemini showed that such failures would occur. All the flights carried stacks of backup charts and instructions for manual procedures to compensate for lost sensors or computers. The moment of firing the final-approach burn could be computed, or the crew could judge it by measuring the elevation angle of the target ahead and above them. Even with complete computer failure and loss of radio link to mission control, the astronauts could use charts to determine when and how large the burn should be—and they did.

The final transfer trajectory placed the chaser on a path that pulled slightly ahead of the target as it climbed toward the target's altitude. Then, as the chaser neared its apogee, it slowed in obedience of the laws of orbital motion and the target began to overtake it. The chaser's final approach was from ahead of and slightly below the target. This basic approach strategy was used for Gemini, Apollo, and Skylab missions. Some variations were tried, and some problems cropped up from time to time. But it proved a simple, robust, workable scheme.

Then, for the space shuttle, the rendezvous maneuver strategy was changed. Rendezvous was only a minor phase of the shuttle's overall mission. Many different relative starting positions were predicted for the shuttle and its target, not just the classic behind/below approach. So the rendezvous scheme had to be extremely flexible, and it had to allow a wide variety of trajectories to converge on a standardized final approach. Instead of overtaking the target on a lower, co-elliptic orbit, the shuttle would swoop up to a point about eight miles behind the target and slightly above it, then gently approach it.

"What's wrong with the way we've *been* doing it?" asked chief astronaut John Young when the strategy issue was raised in 1982. Nothing was wrong with the classic approach, but the shuttle was a different vehicle. Its maneuvering engines were split into forward and aft sections. Once in space, the shuttle flew roof-forward to allow the crew to observe targets through the overhead window. Jets in the nose and tail





fired upward to slow the vehicle near the target. But the forward tanks were not very large, so the rapid approaches and sharp braking of the Gemini and Apollo days had to be replaced with a more gradual final approach. Between 1965 and 1975, planners thought nothing of ordering braking burns of 20 to 40 feet per second during the final hours of the rendezvous. But the shuttle didn't carry enough forward propellant for that. Its braking burns were on the order of two to five feet per second.

Even if there had been enough propellant, the shuttle could never make burns of those magnitudes so close to a target. Most targets would have much less mass than the shuttle, and they would be easily disturbed by the larger craft's rocket bursts. Some targets could even be knocked out of position.

And unlike Gemini and Apollo targets, which had been designed with rendezvous in mind, shuttle targets usually wouldn't have running lights. They would often be passive, sometimes even entirely inert, so optical navigation was impossible at night. The cooperative radars on Gemini and Apollo, with ranges in the hundreds of miles, couldn't be relied upon because the target might not have a transponder, which amplifies the returning echo of the chaser's radar pulse. The shuttle radar could "paint" a passive target at a range of no better than 20 miles. And finally, many of the early reliability problems had been overcome on the shuttle, so most backup techniques were also changed completely.

The new strategy no longer required the chaser to follow the co-elliptical approach. Instead, it moved in a flexible elliptical orbit whose apogee and perigee were adjusted based on ground computations, with the intention of reaching an aim point 40 miles directly behind the target at about orbital noon, or halfway through the sunlit portion of the orbit. At this trailing point, the actual sequence of rendezvous maneuvers began. From here, the shuttle can employ its star tracker to follow the target. The target's position helps the onboard computer to refine the shuttle's true position and motion.

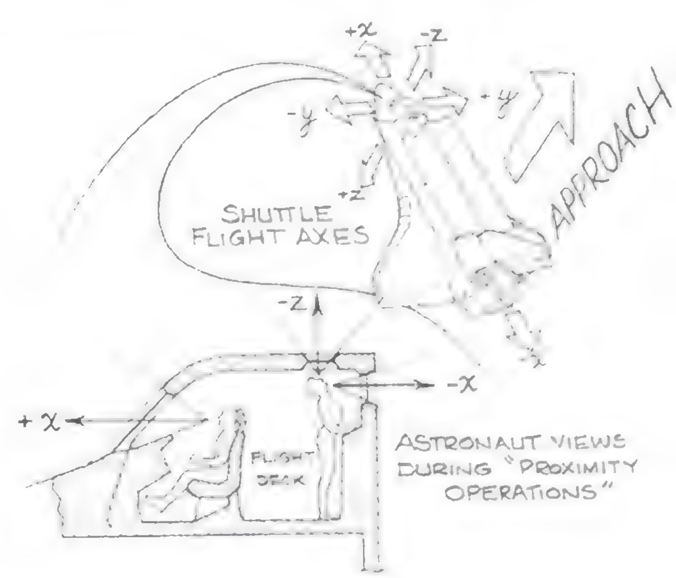
The mission commander is at the back window of the flight deck operating a set of controls, his feet anchored by cloth loops on the floor. But as he looks from the instruments in front of him to the overhead window and a window-mounted sextant-like device called a COAS (for "crew optical alignment sighter"), he alternately bends forward and straightens up. Kevin Chilton, running a computer console from one of the front seats, noticed this incongruous bobbing motion and nicknamed it "the rendezvous hop." As he explains, "It looks like they're back there bouncing to some music."

"Ti," meaning either "transition initiate" or "transfer initiate," depending on who's talking, is a point precisely 40,000 feet behind the target and about 800 feet above it, which is reached near orbital noon. At this point, the chaser is in an orbit that, if uncorrected, would swoop below and then ahead of the target (it's fail-safe, in that no further maneuvers are needed to avoid collision). The standard maneuver will raise the chaser's perigee and shorten the distance to the next apogee from 16 miles to about eight miles, which will put the chaser on a collision course with the target. Alternately, an even larger burn could circularize the chaser's orbit at this point, resulting in a stable standoff relative position at which any necessary repairs or rethinking could be undertaken. This is the "Ti Delay" maneuver, planned for from the very beginning of shuttle rendezvous but never actually implemented until the third attempt at rendezvous during *Endeavour*'s Intelsat mission.

During this phase, radar tracking is better than optical tracker navigation because it works in the dark and provides range and range rate data as well as angles, though the angles aren't as precise as the star tracker's. As the chaser gets closer to the target, its relative navigation using onboard sensors gets better. Ground tracking is too imprecise and episodic to help, so from Ti on in, the onboard navigation provides the primary course control data. A series of mid-course corrections, or MC burns, follows Ti, along with one final planar correction burn.

The chaser is now swooping up from below the target, and it is also pulling slightly ahead. After the last navigated correction burn, the crew switches over to manual control and uses the last navigation strategy. Straightforward and elegant, this technique provides an efficient guide to any further correction burns.

Simply put, the shuttle autopilot is locked into inertial hold, controlling all angle deviations, while the Z axis (straight up) is pointed directly at the target. At the aft control panel, the pilot watches the target through the overhead window and the COAS. If the target drifts off the crosshairs, he makes gentle corrective rocket burns with the hand controller to nudge the crosshairs back toward the image. This technique provides clearcut indications of course deviations because of a feature of the chaser's elliptical orbit: at this point in the orbit, as it is approaching apogee (and the target), the changing slope of the



Future manned visits to the moon or Mars will rely on rendezvous between landers and propulsion modules.

orbital path nearly matches the motion of the line of sight to the target against the stellar background, so the target appears motionless against the stars. This mathematical coincidence was noticed even before the Gemini era, and it was polished into a control technique by NASA rendezvous designer Edgar Lineberry, who later redesigned the shuttle's rendezvous profile. It permits an efficient, easily perceived indication of required course corrections.

Now on a collision course with the target, the shuttle must also slow its approach. Without braking, the shuttle would hit the target at about six feet per second. This positive closing rate was designed to ensure that minor course deviations wouldn't allow the shuttle to fall below the target, but it also must be reduced by rocket pulses. The crew does this at prescribed ranges called braking gates between 2,000 and 1,000 feet, as the shuttle approaches the target from below and in front. The braking burns push the shuttle's path slightly upward, and the craft finally arrives at a point directly in front of the target and about 400 feet away.

Space navigators call the target's velocity vector the V-bar. Since the chaser-to-target relative height difference is now zero, the relative separating rate, or R-dot, is also zero. At this stable offset point, the shuttle can park itself near the target—called "station-keeping"—with little effort. It can get as close to the target as needed and stop to hold a relative position with great stability.

This is a new phase of the rendezvous, when new factors become important. The effects of orbital mechanics are weaker, while the shuttle's effect on the target—from rocket pulses hitting its skin to radar pulses disturbing its circuits—becomes stronger. This is called the proximity operations phase, or "prox ops" in space jargon.

Kevin Chilton notes that this is the mission phase that impresses most outsiders. "Flying side by side at 18,000 miles per hour sounds really risky," he says. "But that would be so only if we had to control that tremendous speed all by ourselves." Actually, according to the laws of orbital mechanics, when two vehicles are orbiting together, their speeds will also be very close. "All we had to do was carefully control their small relative rates," Chilton explains.

At this point, the astronauts are in complete control. Radar data drops out within about 100 feet, so the ground has no information on the relative positions of the two vehicles. The crew does all the final flying by looking out the window.

All these maneuvers produced good results in 1984, when the crippled Solar Maximum satellite was captured and

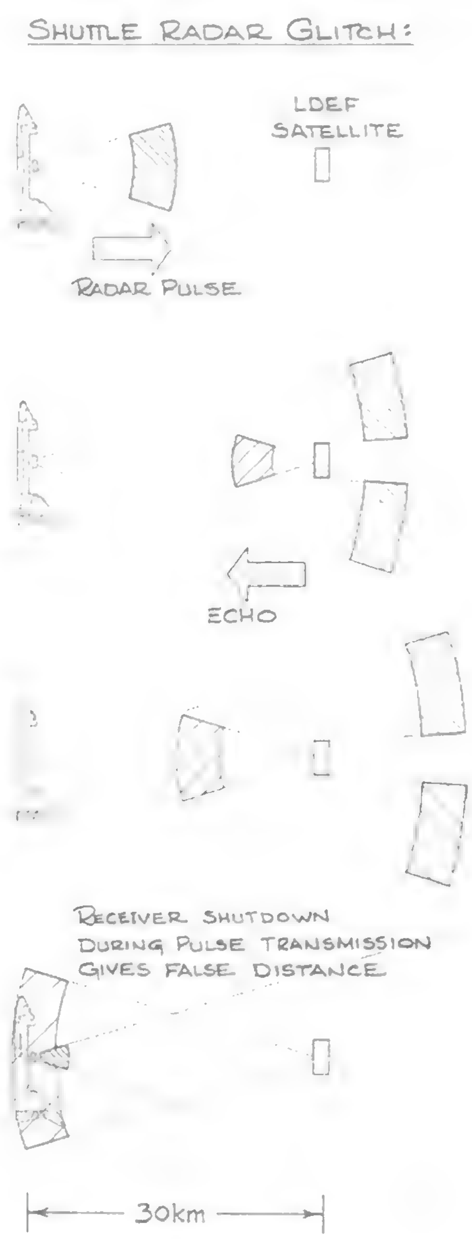
repaired, though it took two approaches to finish the job. Later that year, two stranded communications satellites were retrieved on a single mission, and in 1985 a broken satellite was approached on two separate missions in an attempt to repair it. That same year science satellites were deployed for several days of free flight, then retrieved for return to Earth. Rendezvous shuttle-style began to look routine, but nobody with any spaceflight experience could ever have believed that it really was.

During retrieval of the Long-Duration Exposure Facility (LDEF) in January 1990, I was working the rendezvous from the ground, sitting in the front row ("the trench") in mission control, watching the telemetry and trajectory data on my screens and light panels, and performing the duties of the rendezvous guidance and procedures officer. I got my information from three teams of specialists and reported to the flight director. All our experience kept us wondering what would go wrong next.

When the LDEF was only 30 miles ahead, the shuttle's radar locked onto the target. This was farther out than usual, but the LDEF was a big structure with a big radar return. The navigation team recommended that we feed the radar data into the shuttle's computer, so we did—and soon began to suspect that we'd made a mistake: some course correction burns computed on the shuttle were significantly different from those computed on the ground. Without time or supporting data to help in the selection, I stuck with the onboard answers, but they were distorted enough to throw us off course on the final approach. We'd had this kind of deviation in training, so I knew we could recover (and we did), but the shuttle came zooming in toward the LDEF quite a bit hotter than planned.

It turned out that the radar had two embarrassing features that we'd never seen before. First, at its maximum range, it suffered from an effect called "eclipsing bias." Like all radars, it shut its receiver down just before transmitting a pulse. As a result, a portion of the incoming echo was clipped off, which made the range computation too low. When the shuttle's navigation computer tried to find an orbit that would match those biased range readings it had electronic fits. As the range dropped, the bias dropped until it finally disappeared. Second, the radar unit on the shuttle *Columbia* was the oldest one still in service (those long-range radars are no longer used for navigation), and something went unstable whenever the range measurement was a multiple of about 4,000 feet, with the result that range data become randomly "noisy," further confusing the guidance computers. This quirk was later reproduced in ground testing, but it hadn't been expected and it nearly drove the shuttle too far off course to recover. Fortunately, we had enough reserve fuel, and we had trained for such contingencies.

When Kevin Chilton participated in the Intelsat rescue two years later, our LDEF experience was still terrifyingly fresh in his mind. He was operating the navigation instruments from the commander's front console while mission commander Dan Brandenstein manually flew the spaceship from the aft command console. All the numbers on the data screen looked good, but Chilton wanted real-world confirmation.



He recalls a saying from flying jets on instruments: "It goes 'One peek is worth a thousand sweeps.' That is, one eyeball glimpse is far more credible than anything your radar tells you."

Too busy at the keyboard to move to the window, he asked Bruce Melnick, who was operating the remote manipulating arm, to glance out the overhead window through the COAS sighter. The shuttle's navigation computer was supposed to be instructing the autopilot to point the ship's upward axis directly toward where it thought the target was.

Melnick squinted through the viewer for a moment, then announced that he saw a bright light about ten degrees to the left. "That must be the target," he told a puzzled and somewhat alarmed Chilton. That much angular error implied a significant planar error, which Chilton knew could threaten the entire mission. He floated up out of his seat and went to the overhead window.

"Sure enough, the only light in the field was that one off to the side," he recalls. Then he spotted something else and turned down the brightness on the glowing crosshairs. There, so dim it had first been masked by the illuminated lines, was the target, exactly in the center of the crosshairs. "*That* was a great feeling," he says.

An hour later, as the Intelsat floated tamely just above the shuttle's payload bay, Chilton again took a break from the control console and looked outside. "I was amazed by one idea above all," he recounts. "All the mathematics—all the way from three-two-one-zero-blastoff through the maneuvers to the final rendezvous—all the math was real. I was really impressed that we had been able to compute our way here."

Chilton wasn't exaggerating the importance of the mathematics, nor would he understate the critical role of the flight crews. But he knew better than most people why rendezvous was possible, why Apollo was able to reach the moon, why people can visit space stations. To meet the challenges of orbital rendezvous, the human mind has learned to predict what nature will do and can use those predictions to advantage. Any rendezvous in orbit is more than a mere meeting of two spacecraft; it is a successful marriage of human intelligence and cold reality.

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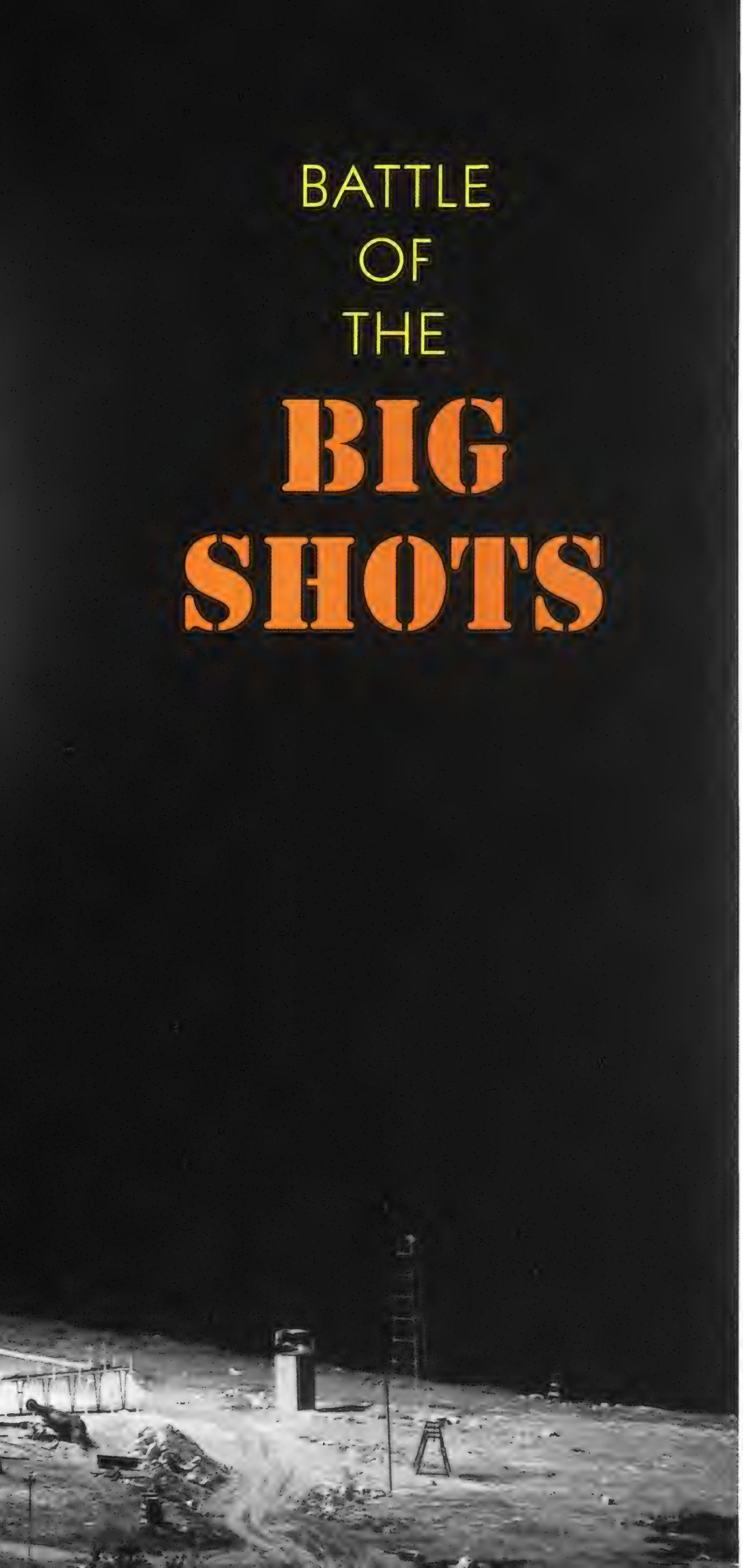
THE LATEST WORD ON TOURS, EXPEDITIONS AND LEARNING ADVENTURES

BATTLE OF THE BIG SHOTS



COURTESY CHARLES H. MURPHY

Gerald Bull's Barbados gun showed that guns had launcher potential—and could also put on a good show.

Yes, you *could* shoot cargo into space with a really big gun. The question is: Which gun would you like to use?

by Frank Kuznik

When a gun this size goes off, you'd expect the brain behind it to be at the trigger, like Captain Nemo at the helm of the *Nautilus*. But no. When the world's largest two-stage light-gas gun fires, John Hunter watches the shots on black-and-white monitors in a bunker control room hundreds of yards away, where you can barely hear the noise, much less enjoy the pyrotechnics.

The shots are much better on videotape. There's a *whoosh* and a roar and then a big blast of flame and smoke as 11 pounds of high-grade plastic slam into a wall of sandbags. Hunter plays the tape twice, then sits at a conference table underneath the monitors to recount the tenuous history of his SHARP (Super High Altitude Research Project) gun, billed as the prototype for a monster version that will one day launch satellites and cargo into space.

"By all rights we shouldn't have survived," he says. "I pulled every trick in the book to keep this thing going. We've run out of money five or six times. I was told to shut the program down on two separate occasions. Somehow I've always found the money to save my butt."

There it is in a nutshell—the dicey state of affairs in the world of big guns. Behind the flashy demonstrations and the promises of a cheap and reliable alternative to rockets, there's the mad scramble just to stay alive, a technology that still works better on paper than in practice, and the task of convincing the "rocket Mafia," as big gun proponents like to call NASA, that their projects can make the transition from weird

science to viable launch systems.

For all that, there's not much question about the feasibility of shooting payloads into orbit. Although the concept is best known from Jules Verne's 1865 novel *From the Earth to the Moon*, two NASA studies done in the mid-1980s concluded that the idea at least makes sense. Guns with the power to penetrate space already exist, though they've been largely devoted to aerodynamic and ballistics research. While significant technical hurdles remain, converting guns to space launchers is less a matter of physics and engineering than one of timing, salesmanship, and funding.

"It has nothing to do with physics," insists Hunter. "It's psychology. There's all these psychological barriers we've got to break down."

Gun launchers do have some fairly obvious drawbacks. They exert massive G-forces on their payloads—up to thousands of Gs, more than enough to turn a human being into jelly (the space shuttle accelerates at a much more stately 3 Gs). Obviously, a gun can launch only very durable space cargo, like water and building materials. Firing satellites into orbit was unthinkable until the relatively recent development of rugged, miniaturized electronics capable of withstanding tremendous acceleration. As a result, even the most ardent supporters foresee no more than a complementary role for big guns, alongside rockets or other spacecraft capable of handling delicate payloads.

Another drawback is payload size. Nothing a gun launches can be larger than its bore—the diameter of its barrel—so large payloads will still have to buy a ticket on a rocket. And because of a fundamental law of physics—"what goes up must come down"—gun-launched projectiles would need rocket-propelled upper stages to nudge them into an orbital track and keep them from falling back to Earth.

The chief argument for gun launchers is that they could provide a low-cost alternative to rockets for the frequent launch of some cargo. Current launch costs run anywhere from $3,000 to $20,000 per pound. Big gunners claim they can launch for $100 to $1,000 per pound, based on an initial investment of several billion dollars amortized over years of frequent launches. "They may be right," says Bob Norwood, acting director of NASA's advanced concepts office, "but there's a lot of unknowns. How much will it cost to build the gun, design it, service it, and, after you've done that, invest in the technology to develop a new class of payload? You can't just focus on the launcher; you've got to look at the economics of the entire mission model."

The spiritual godfather of contem-

At McGill University, Bull (right, with dean of engineering Donald Modrell) designed projectiles he called Martlets, after a creature that appeared on the school's coat of arms.

Adam Bruckner (left) and Abraham Hertzberg (right) have been developing ram accelerators at the University of Washington in Seattle.

Its combustion gases burning behind it, a projectile shoots from the HiRAM ram accelerator. The blast from the tank gun that fires the projectile into the tube is visible at right.

U.S. ARMY RESEARCH LABORATORY

porary big gunners is Gerald Bull, the brilliant Canadian scientist who was murdered in early 1990 when he was on the verge of delivering to Iraqi dictator Saddam Hussein a supergun capable of launching satellites. Bull was a visionary; as early as 1958, he was trying to persuade the Canadian government to fund a satellite gun launcher. Had he been more politically astute, he might have been able to build it—perhaps even for the United States, which co-funded Project HARP (High Altitude Research Program), Bull's spaceshot project. Using a modified powder gun with a 16-inch bore supplied by the U.S. Navy, Bull set up shop in Barbados in 1963 and began setting altitude records with projectiles he had designed.

Charles H. Murphy, the chief of the weapons concepts division at the Army's Aberdeen Proving Ground in Maryland, was a co-worker and close friend of Bull's. Prominently displayed on the wall of his office are two large, slightly faded photographs, one of them the Barbados gun and the other a similar gun fired by the Army in Yuma, Arizona. In 1966 it lofted one of Bull's projectiles to nearly 112 miles, a gun launch altitude record that still stands.

Murphy continues to believe in powder guns as launchers. "Economically the powder gun is the way to go," he says. Used as a first stage, a 400-foot gun with a 32-inch bore, he calculates, could launch a 780-pound payload with a maximum acceleration of 800 Gs.

Bull and Murphy once attempted to interest NASA in a large gun that Bull later transformed into the Iraqi project. Murphy pulls out an artist's conception of the supergun. "If you look at the figures in the drawing you'll see that's a 64-inch gun," he says. "It was really humongous. But it wasn't practical so we turned it into a 32-inch gun and changed the caption on the picture." NASA, however, wasn't interested. "What we've got is an image problem," Murphy says. "It's not high-tech. It's just grubby old technology."

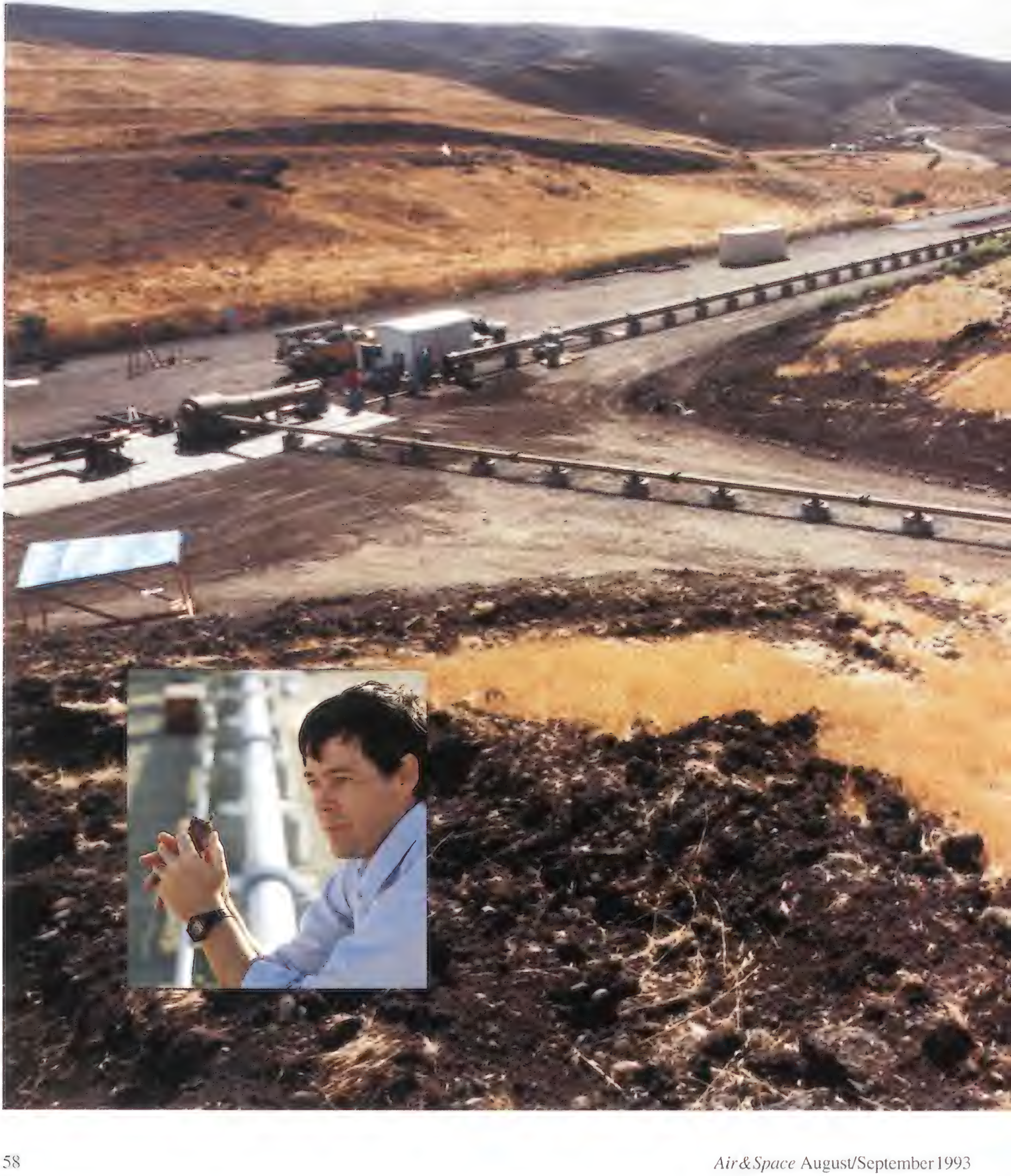
Like big gunners to follow, Bull found a nemesis in rocketry. The Canadian government decided to pull out of the HARP program in 1967, in part because it wanted the money for a rocket project called Black Brant. Bull turned to weapons research and was brilliant in that as well, creating artillery and shells that could outshoot anything on the planet. Yet he still dreamed of building a satellite gun, and apparently believed to his dying day that the supergun he was building for Iraq would be used for satellite launches. But he was also working on missile systems for Baghdad at the time he was murdered, allegedly by Mossad, Israel's intelligence service.

Whatever his faults, Bull remains the archetype of big gunners—exceptionally smart and single-minded, driven by an absolute faith in his ideas, a hybrid of scientist and engineer viewed by colleagues with equal parts awe and skepticism. "This is one of the most unusual groups of people you're going to run into," notes Len Caveny, deputy director for innovative science and technology for the Ballistic Missile Defense Organization (formerly the Strategic Defense Initiative Organization).

Which brings us back to Site 300, a high-explosives testing ground set in the Altamont hills about a 20-minute drive from Lawrence Livermore National Laboratory in northern California. John Hunter's gun sits here in a notch carved out of a hillside, 425 feet of steel pipe shaped like a giant L and latticed with pressure tubes and vacuum pumps. Normally, showing off a pet project is serious business for a scientist—particularly one strapped for funding. Not for Hunter.

"It's irrigation pipe technology," he says breezily, stepping around a cottontail that's taken up residence in a stack of concrete shielding blocks. Pressed to quit kidding, he cracks a big grin. "No, really, I'll bet the average kid's BB gun is more complicated than this. I don't mean to disparage our engineering, but if you look at a Sony Walkman and see all the complicated little parts in it and stuff, that's really amazing. This is simple."

Certainly there's nothing mysterious about gas guns, which have been in use for ballistics and aerodynamic studies for more than 40 years. The most common utilize a light gas like hydrogen and work in two stages: A piston is fired down one end of the barrel, compressing the gas in front of it. When the gas builds to a certain pressure—60,000 pounds per square inch in Hunter's gun—the projectile shoots out the other end at recorded speeds of up to 11 kilometers per second. (That's about 25,000 mph.



LAWRENCE LIVERMORE NATIONAL LABORATORY; PHIL SCHERMEISTER (INSET)

The velocity needed to reach Earth orbit is roughly 7 kilometers/second.)

Hunter modified his gun with an ingenious twist—literally—by bending the normal straight-line design into an L. That was done to simplify firing a test shot into the sky. Now only the second stage, or launch tube, needs to be elevated, not the whole gun.

Though probably the most reliable of the big guns, gas guns face a major problem in "scaling up"—that is, being enlarged enough to accommodate orbital payloads. Hunter's current gun has a four-inch bore; a gun big enough to shoot even small payloads into orbit would have to be at least five times that size. "John's already using the absolute toughest, highest-pressure steel known to man," says Hal Swift, manager of the physics applications division of the Titan Corporation, which manufactures various types of guns for scientific and testing uses. "To go up just from four to six inches, he needs steel that is significantly stronger. And to get that, we may have to be talking to our children."

Hunter hopes to build a bigger gun by replacing the gun's first stage, or pump tube. He's looking into using particle beds, in which uranium pellets rapidly heat the hydrogen, and electrical injection of the gas into the barrel to eliminate the piston. The technology is unproven, but Hunter is as confident it will work as he is about having staked his career on big guns.

"The fundamental problem with going to space is the cost," he says. "Weightlessness, space litter, growing tomatoes—those are all just make-work projects. We're not going to Mars because we can't afford to. Guns may seem like sort of a funny way to put stuff up, but right now they look like the best game in town to me."

Ah, but which gun? Hunter's gas gun is only one of several technologies competing for attention and funding. And in this ego-driven business, not one big gunner has anything good to say about his competitors.

"You won't find any group of people more parochial than the gun commu-

John Hunter (inset) designed his light-gas gun in an "L" shape to simplify launches.

nity," says Miles Palmer, a senior staff scientist with Science Applications International Corporation. "Everybody is dead-set that their technology is the only technology worth anything. I've been sort of a voice in the hurricane saying that if we don't stand together we'll fall separately."

In the 1980s the gun of choice was electromagnetic, thanks to a multimillion-dollar infusion of research funds courtesy of SDI, which envisioned using a device called a rail gun in space. The rail gun uses a set of parallel metal rails to carry powerful pulses of electricity that create a rapidly moving magnetic field to propel the projectile out of the gun. "For a space-based interceptor system where there's no atmosphere to contend with and you aspire to very high velocities, rail guns had a chance to compete with rockets," says BMDO's Caveny. A more recent variation is the coil gun, which uses a series of wire coils instead of rails to generate electromagnetic propulsion.

Both of these guns need huge power sources, and both have problems. Rail guns tend to wear out quickly, particularly along the rails themselves, which are damaged by sliding electrical contact with the projectile. Coil guns have yet to demonstrate that they can shoot faster than 1 kilometer/second, and they need a staggering energy storage capacity—a gun the Air Force was testing used 14,000 car batteries.

SDI also ran up against manufacturing hurdles when it commissioned design studies for full-scale electromagnetic and gas guns. "As I recall, it took approximately five million kilograms of copper to build the rail gun, which is something on the order of one percent of the entire copper capacity in the United States," says Caveny. "The capacitors the coil gun needed—there's not enough capacitor capability in the world to make those. You'd have to build a whole new manufacturing facility."

Worse, the reputation of rail guns plummeted when predictions that they would achieve record velocities turned out to be sheer fantasy. "There was a little bit of suckering that went on there," says Swift. "Computer extrapolations showed these guns getting up to 15, 20, 25 kilometers per second, which is what got SDI excited. But they all crashed at 4 kilometers per second. Beyond that, problems developed that are not completely understood yet. At low velocities you can predict the performance with a hand calculator to within a few percent, then all of a sudden you go into high velocities and the reality drops away. You keep on adding energy and nothing useful happens. Which shows the dangers of expending big blocks of money on extrapolated results."

SDI is virtually out of the big gun business now, though that's due more to budget cutbacks than to lost interest. But the impact of its ill-fated investment in rail guns will likely be felt for some time. "The well has been poisoned by SDI," grouses Hunter. "I run into guys at the Pentagon who spent millions on rail guns and are sort of mad at anybody who comes around with a new gun scheme." Swift agrees: "There's a lot of cynicism and skepticism about hypervelocity gunnery now."

Probably no one is feeling the backlash quite as painfully as M. Bill Cowan, manager of Sandia National Laboratories' electromagnetic propulsion department, which until recently was running the country's premier coil gun project. But half its budget was SDI money, and now Cowan is fighting just to stay afloat. "We're trying desperately [to attract new funding]," he says. "But if you take the wrong approach once, spend a lot of money, and fail, it's going to be a long time before anyone is willing to try again."

Such are the vagaries of the big gun business, which is a lot like a horse race, with different technologies alternately moving into the lead and then falling back as funding for one dries up or another moves to the fore. At the moment, the newest and in some respects most promising contender is the ram accelerator. Just don't call it a gun.

"I want you to be absolutely careful not to call this a gun," says Adam Bruckner, professor of aeronautics and astronautics at the University of Washington in Seattle. "It operates with physics that are totally unlike that of a gun and it has no resemblance to a gun."

Maybe to a trained professional. To the untutored eye, the 52-foot steel pipe structure in the basement of the UW Aerospace and Engineering Research building looks as much like a gun as any of its competitors. Its principle of operation is markedly different, though. Essentially, the ram accelerator is a supersonic ramjet aircraft engine in a tube, with the tube acting as the engine's cowling and the projectile as the central cone that compresses incoming air. In the accelerator, a combustible gas mixture is pumped into the tube and the projectile is fired into it at supersonic speed—at UW, by a gas gun. As the projectile passes through the tube and reaches "super-detonative" velocity, the shock wave of its supersonic passage ignites the gas behind it.


DANNY LEHMAN

M. Bill Cowan saw electromagnetic propulsion fall out of favor when it didn't meet expectations.

The ram accelerator is the brainchild of UW professor Abe Hertzberg, who shares Hunter's feelings about the need for a low-cost alternative to rockets. "I've always regarded the shuttle as a little bit of a silly-ass thing, because we're using a man-rated vehicle to carry toilet paper," he says. "To draw an analogy, you don't use a Mercedes to go to the garbage dump."

Hertzberg and Bruckner's experience epitomizes the big gun business. At first their idea was greeted with skepticism. "We were told we were crazy and it would never work," says Bruck-

ner, who as a student at McGill University worked with Gerald Bull. "People used to be sent here to explain to me why it wouldn't work," recalls Hertzberg. "I'd sit and listen to them and think, *Hell, I can give you better reasons than that why it won't work.*"

Nevertheless, Hertzberg was able to tap an old Air Force buddy at the Pentagon for initial funding and prove that the idea did work. He's kept the program alive by relying heavily on student help and what he characterizes as "brutal hard work and arm-twisting." Even so, the UW program has survived on a virtual shoestring—just $3.5 million over its 10-year life. "We always joke that we could have done this whole project up to now on the Xerox budget that the electromagnetic gun people had," says Bruckner.

Ram accelerator technology is comparatively young, with top speeds of just 2 to 3 kilometers/second. But it gets good reviews from researchers who have started to scale up the UW gun, which has a 1.5-inch bore. "We haven't run into any major hurdles—in fact, the scaling was almost trivial," says Dave Kruczynski, head of the U.S. Army's ram accelerator program at Aberdeen Proving Ground. With a 120-mm (4.7-inch) bore, Kruczynski's ram accelerator, named HiRAM (for Hybrid Inbore RAM), is currently the largest in the world. From its site on an island at the edge of the proving grounds, the accelerator points toward the Chesapeake Bay. A modified tank barrel shoots projectiles into the accelerator tube, which contains a mixture of oxygen, nitrogen, and methane.

"What ram accelerators need to do now is demonstrate they're capable of operating efficiently at velocities up near 7 kilometers per second," says Titan Corporation's Hal Swift. "They face some problems along the way that Bruckner says have conceivable solutions, and I believe him. But we've seen many conceivable solutions that haven't borne out."

The outlook for the other guns? Hunter cleverly built his at an ideal size for aerodynamic testing, guaranteeing interest in it beyond the space community. What he really wants to do, though, is dismantle the SHARP gun and take it to a remote area where he can use it to shoot projectiles into space and try to double or triple the altitude record set by the Yuma gun. "Then maybe the big boys at NASA who only believe in rockets will start to pay attention," he says. Hunter eventually wants to build what he calls the Jules Verne Launcher, which would be capable of sending five tons of payload into low Earth orbit.

Coil guns look dead in the water at the moment, though electromagnetic gun technology isn't; the Army just embarked on a $300 million program to study it for tactical warfare applications. In general, big guns seem to have a more promising future as weapons than as launchers. Even fans of gun launchers, such as Swift, are pessimistic about their chances. "If I was going to bet, I would bet that showstoppers will appear in all of them," he says. "I hate to say that. But for launching payloads into space, if somebody can put together a cheap and dirty expendable rocket system that you could build in numbers, that's what I'd bet on."

It's a sober prediction that has the dull ring of bureaucratic inevitability. And it has none of the imagination or drama of shooting payloads into orbit six times a day from a remote mountainside with the biggest gun ever built. As Hunter said during a recent harangue about a colleague who does nothing but publish papers, "The difference between him and me is: He's writing science fiction. I'm creating it."

NASA

Though it couldn't carry people, a full-scale gun launcher could be just the ticket for rugged cargo.

THE HIGH SIGN

For pilots who tow advertisements, it must be annoying that their most public professional moments are spent droning along in a flight path that a house plant could manage, while the deft displays of timing and control that their trade requires are usually performed for an audience of none. If you have spent five minutes on a beach during peak season, you are probably already inured to the sight and sound of a small airplane humming by with banner in tow, as much a part of the background as the smell of Coppertone. But unless you've visited the ground base of a banner towing operation—usually an isolated corner of a small municipal airport or a flat piece of grassy field near a seaside resort—you've never seen the little dance that banner pilots have to do to pick up their reasons for flying.

"There's a lot of voodoo to it; there's not a lot of science," says Paul Richter, a reticent 31-year-old New Englander who has been flying for National Aerial Advertising for seven years. Take the tow rope, for instance. Some like to tow their banners with a nylon rope; others prefer polypropylene. The length of the rope can also vary, ranging anywhere from 100 to 500 feet. "A lot depends on the airplane you're flying that day and the person," Richter says.

Richter flies a Stearman biplane from National Aerial's base in North Andover, Massachusetts. Aerial Sign Company, which operates out of a five-acre grassy square at North Perry Airport in Hollywood, Florida, has a fleet of some three dozen 50-year-old Piper Cubs and slightly younger Super Cubs. These vintage 1940s airplanes are popular with banner towers because they were built before long, paved runways became common, so they can get off the ground quickly. "Another reason we use Cubs is we're interested in going slow," explains Aerial Sign's David Collette, "and they have good controllability at slow speed."

Aerial ads continue to evolve, but as this Stearman biplane demonstrates, the airplanes that tow them don't change much.

Some advertising companies always have a banner year.

by Linda Shiner

Photographs by Chad Slattery

According to Collette, Aerial Sign has developed its own technique for picking up a banner, which requires hours of training. To hook a banner, a pilot comes in as low as 10 feet off the ground at around 80 mph and aims for a pair of flimsy poles that are only about four feet tall and eight feet apart. Draped across the poles is a loop, which is formed at the end of the banner's tow rope. The pilot attempts to catch this loop with a two-pound steel grappling hook, which is suspended from a rope attached to the tail of the fuselage. The pilot unties the hook from a strut before he makes his descent. As he approaches the poles, which at this point he senses rather than sees, the pilot pulls up so that the hook swings forward, pendulum-like, and under the loop.

The philosophy at Aerial Sign is that the more difficult it is to hook the rope, the more difficult it is to get it caught around a tail wheel or landing gear. It takes practice, and even the most experienced banner pilot will sometimes come up empty. "The only people who don't miss the rope are people who don't tow banners," says Collette.

Banners come in all shapes and sizes, with letters ranging from three to 12 feet. To pull the banners, which are usually made of nylon and weigh an average of 35 pounds, most aircraft have been modified into hard-pulling

Computer-generated photographs enable banner towers to keep up with the latest advertising trends, however brief (opposite).

Scrupulous maintenance is especially important for the older towing craft. At Aerial Sign Company, the maintenance hangar is as colorful as the banners.

Jim Butler owns Aerial Sign Company, one of the largest banner towing operations in the country. His father started the company in 1945, and three of Butler's offspring continue the family tradition.

Beaches and banners were made for each other, so Miami offers a prime aerial venue (opposite).

Before a banner takes to the sky, an intricate arrangement of ropes that will hold it upright must be carefully prepared on the ground (left).

Many tow aircraft date from the 1940s and have been rebuilt several times. Some have as many as 50,000 hours.

tractors. Even in his Stearman, which is modified with a 600-hp engine, Richter feels "a pretty good tug" when he hooks a 30- by 100-foot "Super Skyboard."

It's not uncommon for banner towing airplanes to have been rebuilt several times, as is the case with the Piper J-3 Cub that Jim Butler's father used to start Aerial Sign Company in 1945. "He painted C-O-T-T on the side and flew signs for the Cott Bottling Company, who were looking for ways to reach rural New England with their soft drink," says his son. You can still hear a little New England in his voice. "That one's on its seventh or eighth rebuild. It has over 50,000 hours of flying time." He chuckles. "That's gotta be an all-time money-maker. I've probably made two and half million dollars with that airplane," he says.

The banner towing industry brings in somewhere around $10 million a year, but the big money is in national campaigns. Last Memorial Day weekend National Aerial Advertising flew a campaign to advertise the Fox movie *Hot Shots Part Deux* in eight cities and Universal Pictures' *Jurassic Park* in five more. National Aerial Advertising also has clients overseas. In 1982 Nigerian president Shehu Shagari hired the company to fly banners during his reelection campaign (he won), and this summer Wayne Mansfield, National Aerial Advertising's president, made sales calls in Copenhagen, London, and Prague. "Mansfield is the intergalactic banner towing guy," say Peter Riordan of New York's BBDO ad agency.

Whenever a crowd gathers outdoors, there's likely to be at least a banner pilot or two. Last October four banner towers (as well as three helicopters and three blimps) flew over Atlanta-Fulton County Stadium during the National League baseball playoffs. During spring break, Daytona Beach also draws banner towers. As a matter of fact, at Daytona in 1990, Aerial Sign won a place in the Guinness Book of World Records for towing a 5,000-square-foot Reebok billboard—the sign that has spent the longest amount of time airborne.

College students are a prime target for all sorts of banner advertising. Hoping to boost flagging enrollment in an introductory course, a group of Harvard astronomy professors once hired National Aerial Advertising to fly over campus with a banner that read: "SCI A-17 NOON MWF SCIENCE CENTER HALL D TRY IT!"

While corporate advertising is an increasingly popular trend in banner towing, a large part of the business still involves towing messages for a smaller audience—usually it's a birthday, anniversary, or valentine greeting. The most memorable one that David Collette can recall proclaimed: "JOHN, I LOVE YOU. GET A DIVORCE." The next day hundreds of women with husbands named John called Aerial Sign wanting to know who the client was.

Sometimes delivering the message isn't as easy as it looks. "When I first started back in '76," says Tom King of southern California's Tom King Aerial Enterprises, "I was flying out of Flabob airport [near Los Angeles] and


CHALK'S

I had a personal job over in Banning, 30 miles east." The client said the pilot should look for a house with a swimming pool and tennis court, where he would see a birthday party in full swing. King found a house and party, circled three times, and came back to the base, only to get a phone call asking when he was coming. "Swimming pools and tennis courts are so common out here that I had flown the wrong party," he says, "but we got the job done."

In small operations pilot and ground crew are the same person, but a large outfit like Aerial Sign employs some 35 pilots who fly all over the country but concentrate primarily on the Florida coast "from the Keys to Vero Beach." It's a family operation, and president Jim Butler, a ruddy-faced, jovial man, jokes that he will "deny any charges of nepotism" in its personnel matters. His 30-year-old son Todd is a pilot and also in charge of ground operations. Jim Jr., 25, specializes in flying the specialty signs: a big three-dimensional replica of a beer can or a 75-foot-high computer-generated photograph of rapper Marky Mark in his underwear. Butler's wife Alice has also flown banners. Butler himself, "Mr. B" to most of his employees, has "done every job in the shop." He says he can operate a sewing machine to make the signs as well as the airplane to tow them. "And when daughter Jodi isn't in college," says Butler, "she's the bill collector."

David Collette, director of flight operations, almost seems part of the family. He's been with the company going on 28 years, ever since he was 15 and, while riding a motor scooter on a Florida back road, came upon a man stretching out a long string of big cotton letters. He stopped to see what was happening and ended up joining the ground crew. He never intended to stay with the company so long, but he got hooked when Jim Butler taught him to fly. Now he has 23,000 hours as a banner pilot.

This summer Wayne Mansfield (below) made sales calls in Europe for National Aerial Advertising, which his father founded in 1947.

Not all aerial ads are corporate; personal messages are also a large part of the business (bottom).

Today Collette is a suntanned 42-year-old whose own 18-year-old son has been rolling out the day's banners and readying them for pickup. The temperature is 82 degrees, and only in Florida could there be such a sky in late December. Last year, Aerial Sign flew banners every day save seven. Most of those they lost to hurricane Andrew.

From the northeast a Super Cub skirts the Cadillac dealership on the airport's west flank, then circles back to drop off a banner advertising BARGAINS AT THE BAZAAR. "We always fly patterns *around* the Cadillac dealer," says Collette. "In case a hook drops or something, we don't want to buy a new Cadillac."

With the Super Cub at an altitude of 200 feet, the pilot pulls a handle in the cockpit, releasing the tow rope. The banner buckles and flops uneventfully down, tow rope, hook, and all. The airplane, additional ropes and hooks already attached, circles the dealership again and makes a low pass, as the pilot searches the field for his marker and his next job. Each pilot has his own marker—a blue traffic cone, a pirate's flag, perhaps an old airplane tire painted fluorescent orange—to identify which banner to snag. Today's banners have been rolled out in a north-south direction so that the pilot is heading into the wind for the pickup.

The Super Cub approaches again from the south, descending toward the banner and the loop at the end of its tow rope. It looks as though the pilot intends to land, but seconds before his wings pass over the loop, the Cub pulls up, and sure enough, the hook swings forward, claws the rope, and "GET LUCKY AT DANAI JAI ALAI" peels smoothly off the ground and heads northeast. If all goes well during the rest of the flight, one of the few highlights of that pilot's day is over.

"It takes a lot of judgment to determine the height of the airplane above the ground," says John Wensel, a general aviation safety inspector for the Federal Aviation Administration, which requires new banner tow operations to apply for authorization to fly an airplane towing something other than a glider.

The towing part is easy; it's snagging the banner rope that's difficult. For the truly impossible, try fitting this Super Skyboard into one of Boston's automatic teller machines.

Collette concurs. "There's a safe way to do it," he says. "We have 40 years of experience that taught us how." He and Aerial Sign flight instructor Dennis Lord both emphasize the importance of speed. They tell their pilots to get the airplane's speed up at the bottom of their descent so the pilot will have enough speed remaining at the top of the climb. "A slow airplane is the number-one getter of banner pilots," says Collette.

In the last decade, 24 pilots have been gotten, according to records of the 130 banner flying accidents investigated by the National Transportation Safety Board. Many were attributed to "inadvertent stall."

But the hazards of banner towing generally tend to be far more benign. The one that gets every pilot is boredom. What makes a person want to fly a small tailwheel airplane at 50 mph back and forth for hours with a banner in tow? "It's one of the few jobs left in aviation where you can still fly the airplane," says Collette. "It's stick and rudder. You want to see the houses get smaller? You pull back on the stick. You want to see them get bigger? You pull back on the stick some more."

To those who fly for a living, banner towing may be the equivalent of file clerking, but it's also one of the fastest ways to qualify for the next rung on the ladder—an airline transport rating. Granted, the next rung is a long step. For an airline transport license, the FAA requires 1,200 hours of flight time. That's a lot of trips up and down the beach.

David Collette squints into the noon sun over North Perry Airport and watches another banner pilot charge in low and pull up at just the right moment to hook another sign. While he observes the pickup, he describes the early days when the five-foot letters were made from cotton instead of nylon and spaced between bamboo poles instead of aluminum rods. "You could only tow 25 letters then, and they were *heavy*," Collette says, "and if you got caught in the rain you could hardly fly the thing." Another pilot dips, climbs, and heads for the beach, where, above an audience of thousands, "FESTIVAL FLEA MARKET: EVERYDAY'S A FESTIVAL OF SAVING. SAMPLE ROAD & TURNPIKE" will trail behind him straight and level for hours. Some things in this business never change.

ART BY ANDREAS NOTTEBOHM

ASTRONOMY'S
MOST WANTED

SIXTH IN A SERIES

AT THE POINT OF SINGULARITY

A black hole is the ultimate implausibility: a star at least 40 times the mass of our sun compressed into an almost infinitesimal point. Yet there may be as many as 100 million of them in our galaxy alone.

by Ann K. Finkbeiner

Black holes, when imagined, are unimaginable. But popular culture got used to them anyway. Black holes are the stars of movies, the heroes of books, the byword for all kinds of bad risks. They are over-familiar and all but cliché. Luckily, astronomers are not bored yet. In the last few years, they have found increasing evidence of black holes both in our galaxy and outside it. These days, what's most unbelievable about black holes is that they seem to be real.

For certain stars, black holes are the afterlife. Stars the size of our sun spend their lives burning fuel and radiating light, balancing the radiation's push outward against gravity's pull inward. As a star runs out of fuel, gravity begins to win. The star condenses and shrinks smaller and smaller until gravity's pull is again balanced, this time by the force that keeps electrons from crowding too close together. The star, now called a white dwarf, shines for a while, then gradually cools and dims.

In stars with masses more than eight times the sun's, gravity is correspondingly stronger. These stars die with a bang in supernova explosions, which blow away much of the star's mass. If what remains is less than three solar masses, gravity jams the negatively charged electrons and the positively charged protons together. The opposite charges neutralize each other and the remnant core, now composed entirely of neutrons, is called a neutron star. It has shrunk to about 10 miles in diameter. Matter this compact "beggars description," says Jeffrey McClintock, an astronomer at the Harvard-Smithsonian Center for Astrophysics in Massachusetts. If the Great Lakes were made this compact, they would fit into a bathroom sink. " 'Compact' is the word we like to use," McClintock adds, "because 'dense' doesn't even cover it." Neutron stars shine when they're formed, most brightly in X-rays; they also have magnetic fields that can send out crisp pulses of radio waves.

In stars with masses 40 times the sun's, gravity is strong enough to make the unthinkable happen. These stars also die violently. If the remaining core is bigger than a neutron star—

LOU JONES

Though he finds the structure of black holes hard to imagine, Jeffrey McClintock is reasonably certain that stellar-sized ones exist.

that is, greater than three solar masses—it condenses to nothingness, or near enough to make no difference: to 10^{-33} centimeters. Physicists call this point a singularity and tend not to talk about it because they have no clue as to what happens to matter at these densities. "It most likely goes unstable," says McClintock. "Does it exist anymore? I don't know. It's basically out the window. The elementary particles themselves are torn into fragments whose nature is not known and cannot be guessed." Scientists do know that matter at these densities loses all properties except for mass, rotation, and charge. Says McClintock: "The trees out there, those pearls, the computer—any property they have, [once in the black hole] they don't have it anymore." The physicists' phrase is: black holes have no hair. "That means black holes don't have you-name-it, just-list-it," says McClintock. "Nothing nothing nothing nothing nothing nothing."

McClintock is middle-aged, his hair mostly gray, and he speaks slowly, softly, and deliberately in a voice that would sound good on radio. His gestures are controlled: to show how gas explodes on the hard surface of a neutron star, he brings his hand down fast but hits the desk without a sound. Sometimes he goes dead quiet in the middle of the sentence, absolutely still as though the movie has jammed, then suddenly starts up where he left off. His office is decorated with symbols of the ultimate: geological specimens formed under extreme conditions, pictures of the garden in the Zen temple at Ryoanji with its 15 precisely placed stones on raked sand. When he talks about a white dwarf or neutron star, he cups it in his hands, hunching over it, looking at it intensely. When he talks about a black hole, he straightens and his hands fall apart—black holes can't be looked at, can't be held.

Black holes appear to come in two sizes. The smaller ones are about 10 times our sun's mass; the large ones are millions of times more massive. Astronomers don't know why there are only two sizes—perhaps they simply haven't found the ones in between. They are reasonably sure they've found the smaller variety and strongly suspect that the larger ones exist, because little else explains some observations. That they have found any at all is a little surprising: black holes are, after all, invisible. "It doesn't give you very much," says McClintock. "You're not seeing anything. Nothing. This thing is not available to you." Instead, McClintock and his fellows rely on indirect evidence: if black holes themselves aren't visible, whatever falls into them is. By looking for this evidence, McClintock says, "you can find objects that according to all knowledge have to be black holes. You can pinpoint them, be almost certain of them."

A black hole exists as a profound gravitational pit in the fabric of space-time. Anything approaching the pit circles it like a marble rolling into a funnel. Past a certain point called the event horizon, nothing rolling into a black hole gets back out—not even light. As a result, black holes are detectable only when accompanied by clouds of gas, which circle the black hole in a hot, fast-moving, incandescent whirlpool called

an accretion disk. Black holes are detectable because accretion disks shine. When the gas in a black hole's neighborhood eventually gets used up, the accretion disk disappears and the black hole is virtually undetectable.

The black hole, however, does not disappear. The pit does not go away. Our galaxy, for instance, probably holds 100 million black holes that are born unaccompanied, each with an event horizon the size of a city, "just cruising around out there in interstellar space," says McClintock. Because they are unaccompanied, they are undetectable. "If they went into a dense molecular cloud," says McClintock, "maybe they'd light up enough for us to see them. But I wouldn't count on it." That's not to say a black hole never dies. British physicist Stephen Hawking has theorized that black holes can in some sense evaporate. A black hole of 10 solar masses would evaporate in 10^{70} years. The universe is maybe 10^{10} years old, so a black hole's lifetime can be considered more or less infinite.

Some astronomers are looking for black holes of a *billion* solar masses.

So far, all of this is theory. Evidence of real black holes has come both haltingly and sparely. In the mid-1960s astronomers found unique objects that were too far away, too bright, and too small to be anything but accretion disks around galaxy-size black holes. But the observers were diagnosing by exclusion: they simply couldn't think what else these objects might be.

In 1971 astronomers got their most promising evidence: a hidden source of X-rays in the constellation Cygnus. The source, called Cygnus X-1, has a visible companion, a blue supergiant star whose gas feeds an accretion disk. Cygnus X-1 seems to be a small, incredibly dense body of some kind—most likely a black hole.

Twelve years later, Anne Cowley at Arizona State University found LMC X-3, a star with similar peculiarities in the Large Magellanic Cloud. But astronomers weren't dead certain that either Cygnus X-1 or LMC X-3 was a black hole. Not until the mid-1980s, when better detectors enabled observations of a few more similar peculiar objects, did astronomers become more certain of their diagnoses. McClintock was in on several of these observations.

His job is to look for the smaller black holes. The ones he and his colleagues have found are detectable because each is paired with a visible companion in a binary-star system. The companion stars still orbit the black holes, but are now bloated and stretched out of shape by the singularity's gravitational pull. Because a black hole and its companion are as close as two million miles apart (Earth and the sun are separated by 93 million miles), the companion loses its substance by fits and starts, called outbursts, to the black hole.

In one model of an outburst, a tongue of gas shoots out from the companion and hits the leading edge of the accretion disk a few hours later. The whole disk flares up. Over the next few weeks the gas spirals down through the disk, starting out cooler than the sun at the outer edge and heating up as it moves inward. By the time the gas reaches the disk's inner edge, it's up to 10 million degrees, giving off X-rays, and moving fast. What McClintock calls the last stable orbit around a spinning black hole has a radius of 9.3 miles, which he says is the radius of Route 128 circling Boston. The gas circles the last stable orbit in 0.0005 second, crosses the event horizon at the speed of light, and is gone.

After about a year, the accretion disk is cleaned out of most of its gas and dims again until the next outburst. For every outburst, the companion star loses about a billionth of a solar mass. And because outbursts happen only once every 50 years or so, says McClintock, the companions "won't get stripped all the way down in the age of the universe. And if [a black hole] would eat up its partner like a black widow spider, I'd say: Who cares?" The black hole would become just another of the 100 million undetectable ones currently cruising the Milky Way.

To find detectable black holes, McClintock and his col-

ART BY ANDREAS NOTTEBOHM

leagues look for badly behaved companion stars and signs of outbursts. The outbursts get noticed first, usually by X-ray or gamma ray satellite observatories. In January 1991, Russian and Japanese satellites recorded an outburst of X-rays and gamma rays from a star called Nova Muscae 1991, which brightened by millions of times in low-energy X-rays, the so-called ultra-soft X-rays of around five kilo-electron volts (keV). Nova Muscae also brightened greatly at high-energy X-rays, developing a hard X-ray "tail" extending above 500 keV. Even more intriguing, the star's spectrum had a 511-keV line, a sign of gas so furiously hot that it creates matter and anti-matter, electrons and positrons that annihilate each other and give off gamma rays at exactly 511 keV. After seeing this particular X-ray profile a few times, astronomers have come to believe it is the signature of a black hole: "The ultra-soft flux, the hard tail, and the annihilation line are a label of what the merchandise is," says McClintock. Astronomers are still diagnosing by exclusion, but nothing else in the universe—not even a neutron star—ought to carry exactly that label.

But labels are not certainty. If a black hole is mass with no light, then certainty requires measuring that mass, which in turn requires tracking the orbit of the companion star. With Nova Muscae, the companion star's light was swamped by the visible light of the outburst, so tracking its orbit required waiting a year or so until the accretion disk was cleared out of gas and the outburst was over. By the fall of 1991, Nova Muscae had begun to dim and Ronald Remillard, McClintock's colleague at the Massachusetts Institute of Technology, suggested they apply for time at the Cerro Tololo Inter-American Observatory in Chile to observe the black hole's faint companion, by then at the limits of the telescope's range. McClintock was busy on another project, so he said to Remillard, "Jeez, it's awfully faint, you write the proposal." Remillard did. They were granted time on the telescope but were told to collaborate with another astronomer, Charles Bailyn of Yale University, who had written a similar proposal. "We knew Charles, of course, because he used to be here as a student," says McClintock, "so we all three observed together in April of '92. We had three nights. Two were completely clouded out, horrible."

The third night the skies cleared, and the astronomers determined that the companion was in a small, tight orbit circling something invisible at 254 miles a second once every 10.4 hours. According to Newton's laws governing the gravitational force between two bodies, the orbital time, or period, times the cube of the velocity gives a function of the combined mass. The three astronomers already knew the companion was a dwarf K star with half the sun's luminosity, and that dwarf K stars with this luminosity were likely to have half a solar mass. Now they computed the invisible companion's mass to be at least 3.1 solar masses, give or take 0.4. Anything invisible with a mass above the upper limit of a neutron star—3.0 solar masses—has to be a black hole.

Nova Muscae is the fifth black hole candidate that has both an X-ray label and a measured mass. Though that's not certain proof of a black hole, no one has serious doubts. Says

RICHARD WAINSCOAT

John Kormendy, an astronomer at the University of Hawaii, searches for black holes millions of times more massive than the sun that may inhabit the centers of galaxies. Because a disk of stars is rotating very rapidly in galaxy NGC 3115, he suspects that a monstrous gravitational force—possibly a black hole—lurks at the galaxy's center.

RICHARD WAINSCOAT AND JOHN KORMENDY

McClintock: "Most everyone believes these systems are black holes." The cases for all five appear solid for a number of reasons. One is that the stars involved are relatively bright and well within the range of telescopes. Another is that, with stars, astronomers are dealing with a known quantity. They know how stars are born, live, and die. So 10-solar-mass black holes, though incredible, are not unpredictable.

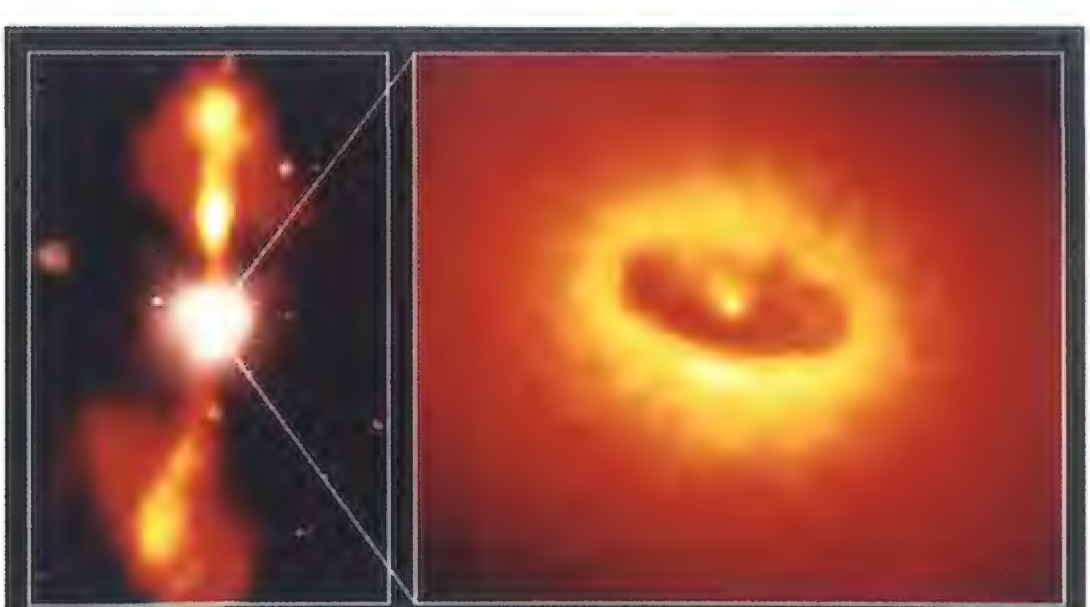
McClintock, however, has colleagues who are more adventurous—astronomers who are looking for black holes of a *billion* solar masses. A black hole this size would be hidden in the nucleus of a galaxy, with a life history that is anything but a known quantity. Most of these possible black holes and their accretion disks are nowhere near within the observing power of even the Hubble Space Telescope. Astronomers can only guess how these huge black holes might form: perhaps a bunch of small black holes in the galaxy's dense nucleus merge, or maybe a small black hole in this dense environment simply mushrooms. "If it's a case of feeling you have a black hole by the tail," McClintock says, "[stellar black holes] are a lot clearer. We understand stars. We don't understand galactic nuclei. We just don't."

If galactic nuclei are unknown quantities, it's not because they are reticent. Active galactic nuclei, the brightest of which are called quasars, can be as bright as a hundred galaxies or a trillion suns. Even more astounding, that brightness can vary by as much as 50 percent in 50 seconds, though more often such variations take days. The speed with which an object varies in brightness indicates its size, so active galactic nuclei can be anywhere from light-seconds to light-days in diameter. The light from active galactic nuclei comes not from stars, which emit a narrow range of wavelengths, but from something that emits *all* wavelengths—from radio waves to gamma rays. Some active galactic nuclei also send out spectacularly long and exquisitely beautiful jets of gas. Anything which is light-seconds to light-days in size, has a brightness of a trillion solar luminosities, can shine in that range of wavelengths, and can power those jets almost has to be a black hole. The size of these black holes, to rephrase McClintock, beggars belief. Their event horizons are not the radius of Route 128 around Boston but the radius of Earth's orbit around the sun.

Measuring the mass of galactic black holes is extremely difficult, like keeping track of a room full of flies. These black holes' companions are not single stars with measurable periods, velocities, and masses but clouds of gas and millions of stars at any distance, at all speeds, and going every which way. "In the best cases, [our estimates of mass] are uncertain to a factor of two or three," says John Kormendy of the University of Hawaii, who looks for galactic black holes. "In the worst cases, to a factor of ten." Says Douglas Richstone, Kormendy's colleague at the University of Michigan: "Because we are uncertain about the orbits of the stars, our error bars [margins of error] are terrible. They're opinion."

One way astronomers can estimate the mass of a galactic black hole is by measuring the velocity of gas presumably circling it—the faster the gas, the more massive the black hole. In the fall of 1992, Holland Ford of the Space Telescope Science Institute and Johns Hopkins University, Walter Jaffe of Leiden Observatory, and Robert O'Connell of

Though scientists have no substantial evidence that galaxy NGC 4261 harbors a black hole, a photograph taken by the Hubble telescope in visible light offers a striking image of how an active black hole might affect a galaxy. The dark doughnut of cold gas and dust some 360 light-years across surrounds what appears to be a white-hot accretion disk of rapidly spiraling gas (right). Like some active galactic nuclei, NGC 4261 ejects long streams of gas from its center (left).


WALTER JAFFE AND HOLLAND FORD

BRETON LITTLEHALES

Douglas Richstone, an astronomer at the University of Michigan, wants to know how the evolution of a galactic black hole affects the evolution of the entire galaxy.

the University of Virginia used the Hubble telescope to observe an active galactic nucleus called NGC 4261. They found gas near the center moving at 2,170 miles a second, suggesting a black hole—if it's there—of 10 million solar masses.

But gas is not a particularly trustworthy indication of mass. "The trouble with gas is that it's hellishly responsive," says Kormendy. "It's very easy for anything to spew out gas at large velocities." Gas is lightweight and easily moved by radiation pressure, magnetic fields, or explosions. Fast-moving gas would certainly accompany a black hole, but it does not specify one. "If you asked me [about NGC 4261], I'd bet ten dollars there's a massive black hole in there," says Richstone, "but I wouldn't bet the car." Kormendy says he'd go to $20, but otherwise he agrees with Richstone. "Not even *my* car," he adds.

Another argument for a black hole in NGC 4261 is in a photograph taken by the Hubble. The image shows a white-hot center that may be gas being pulled into an accretion disk. It's surrounded by a dark doughnut of gas and dust 360 light-years across. The whole thing is embedded in a halo of light from stars outside the doughnut in the surrounding galaxy. "The geometry is what everyone would like to believe [of a black hole]," says Richstone.

But neither geometry nor the motion of gas is a particularly good argument for black holes. The best evidence would be the motions of circling stars. Unfortunately, in active galaxies—ones whose nuclei are actively accreting—stars are harder to see. McClintock would say NGC 4261 is continuously in outburst. Gas and torn-up stars spiral in through the accretion disk, releasing the equivalent of several hundred million solar luminosities in all wavelengths. In this storm of light, the evidence of gas in an active galaxy's spectrum is obvious, but evidence of stars is much more subtle. With active galaxies, says Alan Dressler of the Carnegie Observatories in Pasadena, California, "whenever you have a telltale sign, you also have a spotlight in your eyes. The best way of finding [black holes] is to look in galaxies that are inactive."

Inactive galaxies are just regular galaxies, which perhaps were once active but whose accretion disks have been stripped down and no longer shine. Without the spotlight, astronomers can find evidence of stars by examining these galaxies' spectra. Kormendy and Richstone, building on work by Dressler and John Tonry of MIT, have just finished canvassing the nearest inactive galaxies for black holes. They chose the brightest galaxies, whose nuclei were large and dense with stars. In the nuclei of 14 galaxies, Kormendy, Richstone, Dressler, and Tonry, working singly and in various pairs, first estimated

the amount of mass from the amount of starlight: the more light, the more mass. Then they compared that mass to the mass indicated by the velocity of the stars. If the velocity implies more mass than the light does, then some of the mass pulling the stars has to be dark. It could be burnt-out white dwarfs, neutron stars, some other kind of dark matter, or a black hole.

> **"Chuck an entire solar system into a black hole and the thing would hardly even increase in size."**

True, the stars in a galaxy's nucleus move like a roomful of flies, but they do have an average speed and a net direction. (It's that "average" and "net" that in part give those large margins for error in calculating the mass.) The scientists found three galactic black hole candidates, including M32, a satellite galaxy of Andromeda whose stars were moving at 53 miles a second, indicating a black hole of three million solar masses.

In 1992, Tod Lauer of the National Optical Astronomy Observatories in Tucson, Arizona, and Sandra Faber of Lick Observatory in Santa Cruz, California, found evidence of a black hole in M32 by examining the galaxy's structure. They used the Hubble telescope to map the way starlight gradually intensifies toward the center of M32, forming a distinctive "cusp" or concentration of light. The appearance of a cusp is consistent with the gravitational signature scientists have predicted for galactic black holes, whose immense gravity would undoubtedly alter the structure of the galaxy's nucleus. At M32's center, the concentration of stars is so great, says Lauer, that the night sky is brighter than 100 full moons—a person could literally read by starlight.

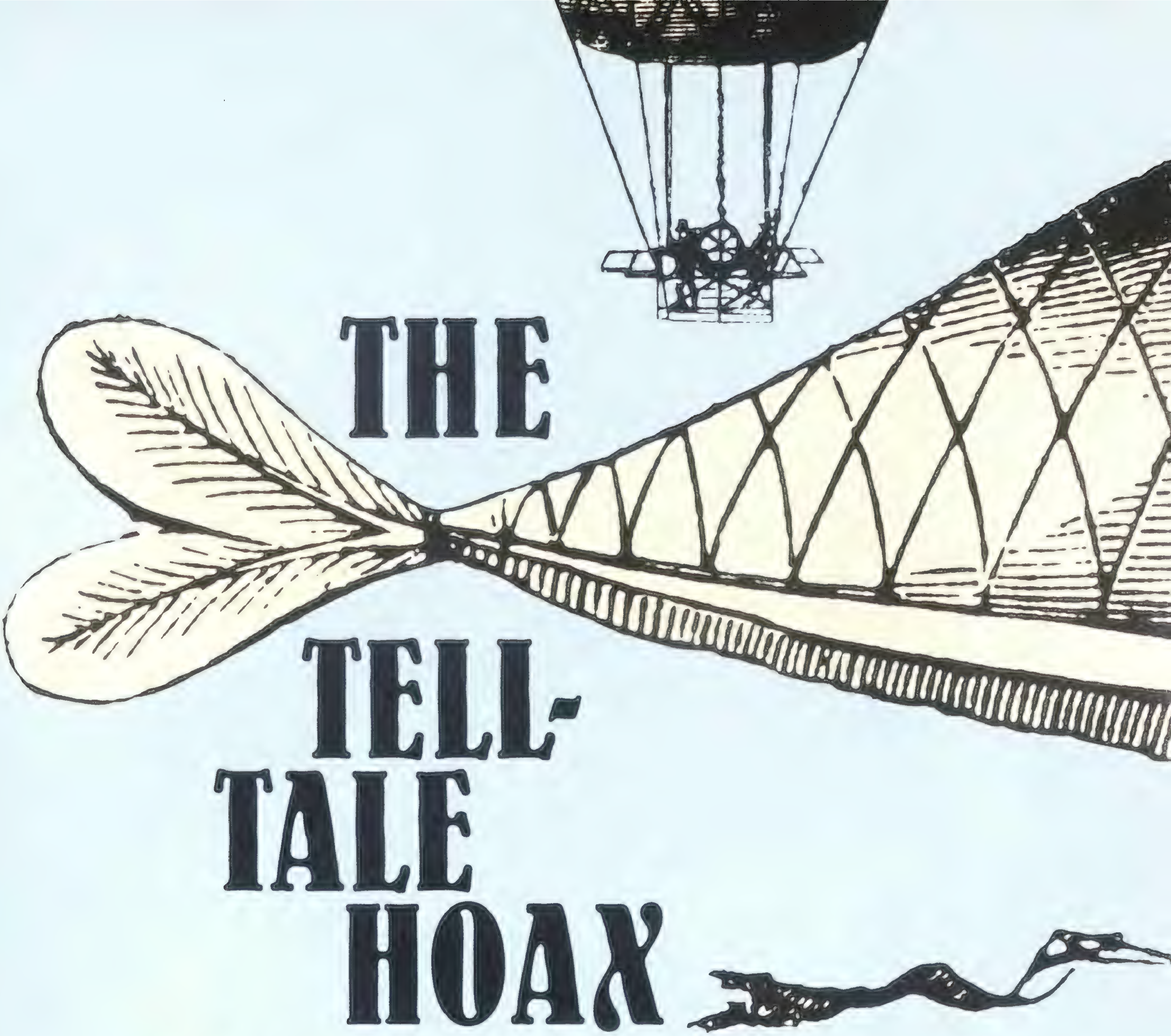
Lauer found a similar cusp of light in the active galaxy M87. As with Ford's NGC 4261, the pictures themselves are almost convincing, but cusps of light like this are corroboration only. Kormendy has observed galaxies whose centers are just as "cuspy" as M32's but which contain no galactic black holes. A cusp, says Dressler, "is suspicious, it's suggestive, it ain't proof."

One begins to wonder why rational, intelligent people would devote their professional lives to searching for indirect evidence of something that, however dramatic, is still invisible and probably irrelevant to the human condition. In fact, few astronomers do devote their research primarily to black holes. Kormendy investigates them, but he thinks of himself "as a person who studies the choreography of stars in a galaxy. This [instance of choreography] is the most interesting—we think it's caused by something truly spectacular." Ford wants to know what active galactic nuclei are and how they operate. Richstone says he wants to understand how the evolution of a black hole fits in with the evolution of the rest of the galaxy. Dressler is most interested in distant galaxies, including quasars, and would like to "clean up why quasars emit so much light. Black holes," he says, "are not one of my life's abiding interests."

That leaves McClintock. "I can't think of anything that actually exists that's more mysterious than the interior of a black hole," he says. One mystery is imagining their scale. "You've cleaned all the planets out of the solar system, cleaned out 20 sets of planets, you take it all and chuck it into one of these 10-solar-mass black holes, the thing would hardly even increase in size. One Earth mass to ten solar masses? It's *nothing.* The event horizon will get one ten millionth bigger—it'll say, Thank you, tiny burp. And then you've *lost everything.*"

Maybe what McClintock likes about black holes is the oxymoron of an impossible reality. "We've got things that according to all the physics we know today are too massive to be neutron stars," he says. "And if they're any kind of star at all, they're some kind of incredible object with incredible physics that we don't even have an inkling what it is. I wouldn't feel bad if we were wrong about black holes. It just doesn't feel good this way. It doesn't leave you with a shred of hope that you can understand things." Then he adds, "You asked why. I can't think of anything more fascinating that I am able to work on."

ART BY ANDREAS NOTTEBOHM



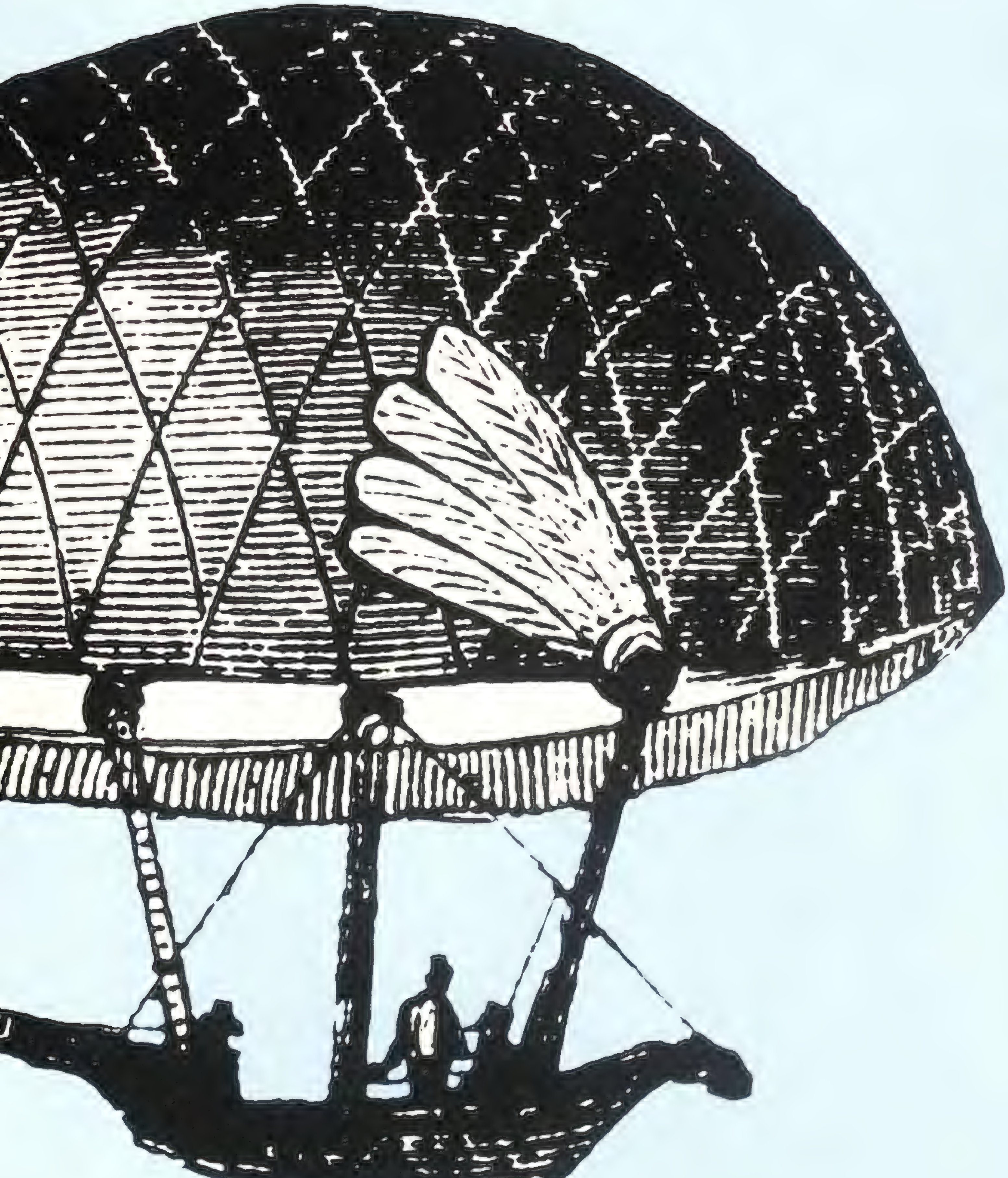
THE TELL-TALE HOAX

In which one E.A. Poe attempts to dupe the entire city of New York.

NASM (2)

"We stop the press at a late hour," read a dramatic announcement in the *New York Sun* on Saturday morning, April 13, 1844. "[W]e are just put in possession of full details of the most extraordinary adventure ever accomplished by man. *The Atlantic Ocean has been actually traversed in a balloon and in the incredibly brief period of Three Days!*"

According to the *Sun*'s bulletin, the celebrated balloonist Monck Mason had flown from North Wales to a site near Charleston, South Carolina. The editor explained that he'd hurried the news into print, and then—in the 19th century equivalent of a news anchor saying "Film at 11"—promised "by 10 this morning to have ready an Extra with a detailed account of the voyage.... It will embrace all the particulars yet known."



by Richard Sassaman

Across the ocean by balloon! As the morning passed, crowds began gathering outside the *Sun* building in lower Manhattan, hungry for details of the historic feat. One reporter on the scene wrote later that the area "was literally besieged, blocked up—ingress and egress being alike impossible, from a period soon after sunrise until about two o'clock P.M.... I never witnessed more intense excitement to get possession of a newspaper."

When the *Extra Sun* finally appeared, a single seven-column sheet printed on only one side, its headlines trumpeted "ASTOUNDING NEWS!" about the "SIGNAL TRIUMPH OF MR. MONCK MASON'S FLYING MACHINE!!!" The papers were instantly snatched up. The reporter "tried, in vain, during the whole day, to get possession of a copy."

As it turned out, he didn't really need one. He already knew every detail of the century's most "astounding" and "extraordinary" aviation adventure. He had made the whole thing up.

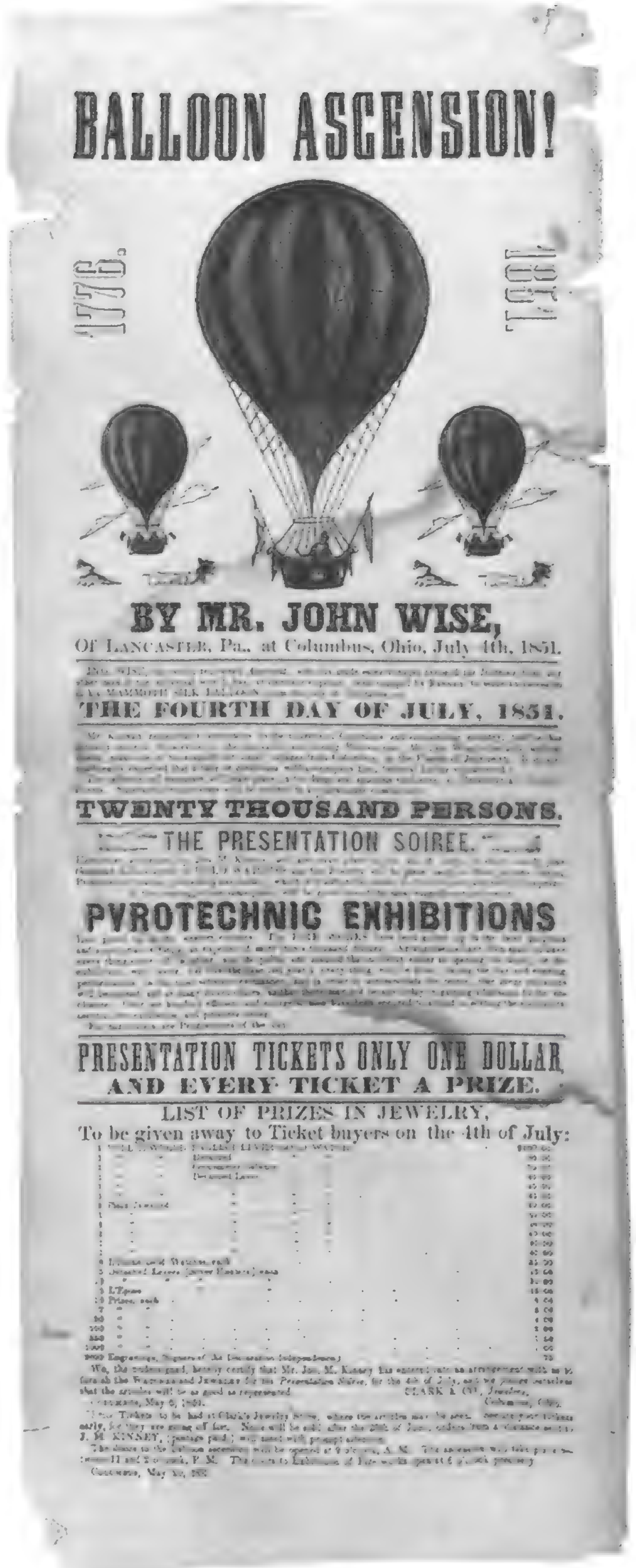
This particular reporter had a unique gift for telling fanciful tales. Then 35, he had just started acquiring a reputation as a writer of haunting poetry and macabre short stories. His name was Edgar Allan Poe, and he had arrived in New York City only seven days earlier, broke and des-

In his transatlantic tale, Edgar Allan Poe (opposite) played on the enthusiasm for ballooning that swept the nation in the mid-1800s. During that period inventors turned out a plethora of balloon designs, some intricate, some fanciful (above).

perate. Writing to his mother-in-law to announce that he and his wife Virginia had made it to New York, Poe reported, "We have now got 4$ and a half left. Tomorrow I am going to try & borrow 3$...." The *Sun* reportedly paid the writer $50 for his ballooning story.

The paper's editors had good reason to believe that their exclusive would find a large and eager readership. For nearly 60 years, New Yorkers had repeatedly demonstrated their fascination with balloon flights. The person who had introduced them to the spectacle of ballooning, an Englishman named James Deeker, had funded the construction and ascents of three balloons by soliciting contributions in New York City newspapers. He launched his first balloon from Manhattan on August 7, 1789. Six weeks later, at Deeker's third launch, two-thirds of the city's citizens showed up.

In the late 1700s, New York City's romance with ballooning took some curious forms. A play titled *The Air Balloon* opened downtown, and a tavern named the Balloon-House set up shop on Broadway. In 1800 the city's citizens could take a stroll to see the Great Mustapha, a 30-foot balloon shaped like a Turk (unfortunately, Mustapha was a few generations too early for the Macy's Thanksgiving Day Parade). And of course there were the actual ascensions themselves. In those years, dozens of daredevils did for balloons what the barnstormers of the 1920s and '30s would do for airplanes, staging theatrical flights that the public gladly paid to witness. But these journeys were comparatively short. At the time the *Sun* ran its story, the world distance record for balloons was 500 miles. An Atlantic crossing—a trip more than 10 times that distance—must have strained the credulity of the crowd gathered outside the *Sun* building that day.



The report began with prescient optimism: "The great problem is at length solved! The air, as well as the earth and the ocean, has been subdued by science, and will become a common and convenient highway for mankind." The balloon Poe had invented for the journey, the *Victoria*, would have been more properly called an airship. It was shaped like a blimp, self-propelled, and steered by a rudder. This design would have come as no surprise to New Yorkers who followed the progress of aeronautics. Several U.S. inventors were applying for patents for such craft. One designer, Rufus Porter, had published drawings of several versions of his "travelling balloon" in his newspaper, the *New York Mechanic*. For one design Porter suggested that the balloon could be propelled by four Archimedes' screws. That was the form of propulsion Poe selected for the *Victoria*.

Choosing a real champion balloonist as the hero further heightened the credibility of Poe's story. In 1835 Monck Mason won the world record for distance by traveling the 500 miles from London to Weilburg, Germany, in 18 hours. Alert readers of the *Extra Sun* would have calculated that in crossing the Atlantic, Mason had somehow managed to better that record-breaking speed by more than 40 mph.

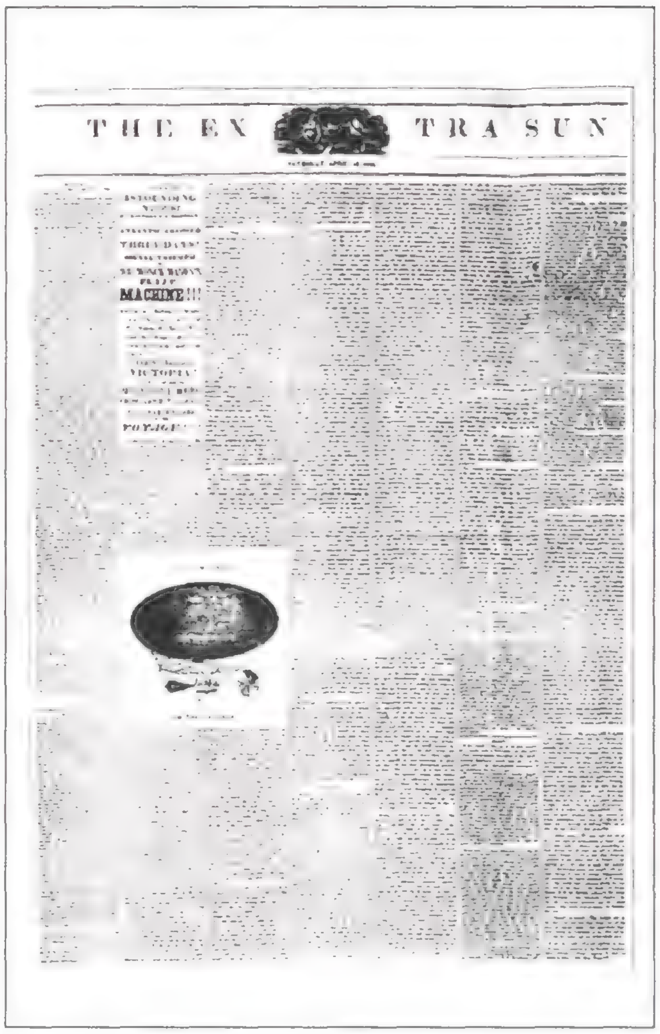
Mason had published his own account of his 1835 flight, and it appears that Poe used this chronicle, as well as another article Mason wrote, describing the balloonist's successful "ellipsoidal" model, to get aeronautical details for his transatlantic story. Poe also worked in bits and pieces from a number of other writings, as well as original material that would fill in the gaps. The notion of the record-breaking flight he almost surely got from an article entitled "Aerial Voyage," which described the plans of a balloonist named John Wise to traverse the Atlantic in three days. The piece appeared in the June 21, 1843 edition of the *Dollar Newspaper*; as it happens, that issue also carried an excerpt from a short story by Poe.

The writer had tried his hand at such literary amalgams before. Though he had once accused fellow poet Henry Wadsworth Longfellow of "bare-faced and barbarous plagiarism," Poe himself was not above "wholesale pilfering of long stretches of descriptive material from other books," according to biographer Kenneth Silverman. Poe had borrowed freely from other writers to create an earlier hoax, "The Journal of Julius Rodman," a supposedly true account of men crossing the Rocky Mountains.

Poe's balloon tale did include a few details that were a bit

Poe took his inspiration from real aeronautical developments of the day, such as the adventures of John Wise, essentially a balloon barnstormer (above); Wise himself had proposed a three-day transatlantic crossing. The writer gave his fictitious balloon a blimp-like shape probably because contemporary inventors were interested in similar designs (opposite).

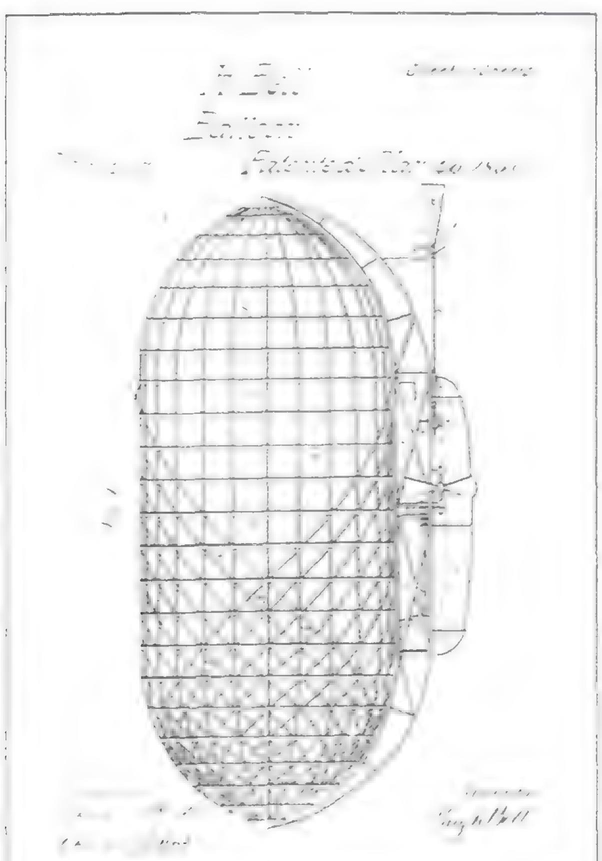
on the outlandish side. Most flights until that time were solo; occasionally the balloonist would take along one passenger or at most two. The *Victoria*, with its unspecified but "vast dimensions," carried eight. The balloon also held "barometers, telescopes, barrels containing provision for a fortnight [presumably in case of a forced landing in the wilderness], water-casks, cloaks, carpet-bags, and various other indispensable matters, including a coffee-warmer...."


THE EXTRA SUN

MACHINE!!!

Besides Mason, three of the voyagers were real live Englishmen. Robert Hollond (spelled "Holland" in Poe's account) had financed Mason's record-setting trip to Germany and had also been a passenger. Inventor William Samuel Henson had patented a kind of proto-airplane he called the "Aerial Steam Carriage." And William Harrison Ainsworth was a popular novelist whose books Poe sometimes reviewed. The other four characters appear to be fictional.

The group supposedly had scheduled a routine flight across the English Channel to Paris. After heading out to sea, they turned east toward France. Everything was working fine until the steel rod connecting the spring of the screw with the propeller was "suddenly jerked out of place." Out of control, the *Victoria* began sailing along at 50 to 60 mph, and by the time the men secured the loose rod, they were way off course. At that point Mason is said to have recorded in his diary, "Mr. Ainsworth made an extraordinary, but to my fancy, a by no means unreasonable or chimerical proposition"—that is, that the group take advantage of the gale-force winds and try to reach North America.



NASM (3)

Except for "odd noises and concussions in the balloon," caused when expanding gas cracked the ice that collected on the balloon's skin, the voyage passed uneventfully at 25,000 feet. Finally, after 74 hours, the men saw the coast of South Carolina, at which point Ainsworth, who was keeping his own diary, recounted: "We have crossed the Atlantic—fairly and *easily* crossed it in a balloon! God be praised! Who shall say that anything is impossible hereafter?"

An hour later the *Victoria* touched down near Fort Moultrie on Sullivan's Island, a place that fictitious passenger Mr. Osborne knew well through "having acquaintances" there. In fact it was Poe who knew Fort Moultrie well; he'd served in the Army there 16 years earlier, and he had also set his story "The Gold-Bug" on the island.

No record documents the manner in which Poe's hoax was exposed. Legend has it that the author himself showed up drunk outside the *Sun* offices and began warning customers that the whole affair was a fake. Whether that indeed happened, some people undoubtedly suspected the worst from the beginning—the *Sun*, after all, was the paper that had previously given the city Richard Adams Locke's notorious "Moon Hoax." That series, published in August 1835, claimed that English astronomer Sir John Herschel, using a powerful new telescope at the southern end of Africa, had seen four-foot-tall, copper-colored, winged human creatures walking around on the moon (see "Heavenly Hoax," April/May 1986). The tale had increased the *Sun*'s daily circulation from 2,500 to 19,000, at the time the largest newspaper circulation in the world.

When the *Sun* came out with its transatlantic bulletin, other papers were quick to pounce on it. But though they denounced the piece as a hoax, what really seemed to gall them was the story's execution. The *New York Herald* hotly condemned the *Sun*'s editor, Moses Y. Beach, as a "blundering blockhead" for not having used a better writer. And the *Saturday Courier* sniffed that the "Moon Hoax" was at least "an ingenious essay; but that is more than can be said of this 'Balloon Story.' "

On April 15 the *Sun* printed a reluctant retraction, saying that "the mails from the South" hadn't brought confirmation of the balloon's arrival and thus the editors were "inclined to believe that the intelligence is erroneous." Still, the paper added, the *Extra* had been "read with great pleasure and satisfaction" and the editors "by no means think such a project impossible."

Many readers felt the same way. Poe had fleshed out his story with a good deal of authentic-sounding technical detail—one scholar later calculated that more than 25 percent of the text can be directly traced to Mason's two ballooning articles alone. But if the author learned anything from the whole escapade, it was probably that all the technical detail in the world will only fool some of the people some of the time. Six weeks after his tale had appeared, Poe recounted: "Of course there was great discrepancy of opinion as regards the authenticity of the story; but I observed that the more intelligent believed, while the rabble, for the most part, rejected the whole with disdain."

Surviving the Bloody 100th

A Wing and a Prayer: The "Bloody 100th" Bomb Group of the U.S. Eighth Air Force in Action over Europe in World War II *by Harry H. Crosby. HarperCollins, 1993. 352 pp., b&w photos, $27.50 (hardbound).*

"The first time I ever saw a B-17 land," recalls Harry Crosby in this fascinating memoir, "it came in at night and crashed, killing the entire crew." It was not a fitting introduction to the warbird that would save Crosby's life more than once during his tour of duty in Europe. As a navigator on 37 bombing missions during World War II, Crosby learned that "a B-17 could get its crew back on one engine. Even with half its tail torn off or with a huge, gaping hole in the wings, fuselage, or nose, a good pilot could get his Fort and his crew back to the base."

That's just what Crosby's pilot, Captain Ev Blakely, did during the mission that inspired the book's title. Shredded by flak over Bremen on October 8, 1943, Crosby's airplane limped home alone with both starboard engines dead. Along the way, its gunners shot down 10 Luftwaffe fighters that attacked it.

Crosby's unit, the 100th Bomb Group, had a cavalier disregard for flying tight formations. "That's why all the other groups like to fly with the 100th," a colonel from another unit told Crosby. "The Luftwaffe go to them instead of to us."

Perhaps partly as a result, the outfit suffered staggering combat losses—12 of 13 crews did not come back from one mission—and thus earned the label "Bloody 100th." But under the iron fist of a new commanding officer named John Bennett, says Crosby, "our wonderful mob became a war machine."

Of all the anecdotes that Crosby has scattered through *A Wing and a Prayer*, the most affecting is the story of how a B-17 crew got rid of their dangerously unstable navigator. They convinced the man that their bomber had been disabled by flak, whereupon he alone bailed out—over Germany. Also not to be missed is Crosby's explanation of how his love for Beethoven's Fifth Symphony saved Bonn from destruction.

If it all seems a cut above your average combat memoir, that's because Crosby is not your average memoirist. After earning a Ph.D. at Stanford under Wallace Stegner, he went on to direct the Writing Center at Harvard. Perhaps that is why he succeeds in putting readers not just in the cockpit but inside the minds of the men who flew the airplanes. Here he is, for example, recounting a typical takeoff of his flying fort from the East Anglia air base: "Green-green flares. All four throttles forward. Engines roar. Brakes off. The creaking starts. The terrain rushes by. Farmer Draper with his horses. He waves. Funny kind of war."

—Allan Fallow is an editorial director at Time-Life Books in Alexandria, Virginia.

CURATOR'S CHOICE

The Politics of Aircraft: Building an American Military Industry *by Jacob Vander Meulen. University Press of Kansas, 1991. 292 pp., $35.00 (hardbound).*

This groundbreaking analysis, written by a former fellow at the National Air and Space Museum, is a sorely needed scholarly treatment of the aircraft industry's formative years. Although some argue with the book's premise that Congress and the military retarded the industry's development, the book contains a wealth of information about production, labor and military relations, and the beginnings of the military-industrial complex.

—Dominick A. Pisano is a curator in the aeronautics department of the National Air and Space Museum.

Zero Three Bravo: Solo Across America in a Small Plane *by Mariana Gosnell. Knopf, 1993. 352 pp., b&w photos, $25.00 (hardbound).*

One summer day, "when even the leaves on the trees in Central Park had an oily film on them and there wasn't anything on the streets that didn't seem sad or hurt or tired or ugly," *Newsweek* reporter Mariana Gosnell decided that she had had quite

PHILIP ROSS

enough of Manhattan. She packed her 1950 Luscombe with clothes, charts, and snacks, then took off from her home airport in Spring Valley, New York, for a 10,000-mile three-month tour of the United States. (Though Gosnell avoids dating the flight, stating only that it started "not so very long ago," a chapter on watching Bryan Allen go after the Kremer Prize in the *Gossamer Condor* pegs it at 1977.)

This sort of journey has been the basis for a number of books by pilots, but few have appealed to readers other than aviation buffs. *Zero Three Bravo* deftly transcends those limits. Gosnell is a fine storyteller, insightful and unpretentious. Her cast of characters comprises those whose livelihoods depend on little airports—banner towers, fixed-base operators, ag pilots, and wives, husbands, and kids. Gosnell re-creates them for us: the good, the bad, and the odd. She also paints the landscape and circumstances in which they live and which, in many cases, has sanded down or rounded out their personas.

Gosnell wisely gives these characters starring roles and restricts her own appearances to cameos, which is why her book should appeal to all readers. But there's plenty of flying—Gosnell brings her airplane to life as vividly as the acquaintances she makes on her journey.

—Patricia Trenner is the departments editor of Air & Space/Smithsonian.

TELEVISION

For television coverage of shuttle missions, tune in to the space agency's cable channel: NASA Select. It's in the public domain and available to any local cable company, or it can be accessed through GE SATCOM-F2R, transponder 13. The frequency is 3960 MHz with an orbital position of 72 degrees west longitude. Missions are covered around the clock. Between missions, NASA runs documentaries and teleconferences.

SECOND GLANCES

(An occasional reminder of noteworthy books that might have been overlooked when originally published.)

From A-3 to A-10 *by Captain Gerald W. Fay. Sunflower University Press, 1988. 258 pp., b&w photos, $15.00 (paperback).*

Expect a diary, not literature, from this career transport pilot. The bulk of his book is devoted to large, recip-powered transports, and as these products of aviation's Golden Age fade along with the people who remember them, Fay's detailed—at times humdrum—accounting becomes more valuable with time.

—George C. Larson is the editor of Air & Space/Smithsonian.

Peter Nevsky and the True Story of the Russian Moon Landing *by John Calvin Batchelor. Henry Holt, 1993. 499 pp., $25.00 (hardcover).*

Narrated by a former cosmonaut named Peter Nevsky, whose father was the finest Russian ace of World War II, this ambitious novel focuses on the U.S.-Soviet space race. I was most curious to see how an American would write about the highly secretive Soviet space program, a world to which he was a stranger.

While I was ultimately let down by the fiction, the author nonetheless manages to make convincing a plot in which a Russian manned mission to the moon is launched prior to Apollo 11. The language in this tale is rich with robust Russian jargon and the story is set in real places like Star City (here called Starry Town), the Cosmodrome, and Lubyanka, the headquarters of state security. From time to time the reader will discover the formerly classified names of Russian scientists, but the actual heroes of the novel are ingeniously invented.

Now that the Soviet Union—or what remains after its dismantling—is no longer surrounded by an iron curtain, rocket designers and former intelligence officers are coming out of the closet to tell their own stories. In light of these revelations, the appeal of this historical fiction and other similar works remains to be seen.

—Roald Sagdeev, formerly head of the Soviet Space Research Institute, is now a professor of physics at the University of Maryland.

COMPUTER SOFTWARE

Shuttle *by Virgin Games, Inc. (18061 Fitch Ave., Irvine, CA 92714). Available for MS-DOS and Macintosh. Suggested retail price: $49.95.*

This computer-based simulation does a remarkable job of re-creating the experience of piloting a space shuttle. After completing the Approach and Landing Test flight mission, users have a choice of nine other missions, which include launching the Hubble telescope, using the Remote Manipulator System, recovering a satellite for repair, and launching a secret military satellite. Users can also undertake spacewalks and operate the Manned Maneuvering Unit. Each mission can be customized to launch or land at either Kennedy Space Center in Florida or Vandenberg Air Force Base in California. PC users looking for breathtaking graphics may be disappointed. For the would-be shuttle pilot, however, this software, along with its highly entertaining and informative manual, very nearly justifies the cost of buying a computer.

—Joe Rudich is a freelance writer in Cottage Grove, Minnesota.

Secret Weapons of the Luftwaffe *by Lucasfilm Games (P.O. Box 10307, San Rafael, CA 94912). Available for IBM PCs and compatibles. Suggested retail price: $69.95.*

Say goodbye to your spreadsheets after trying this utterly addicting computer-based flight simulator. "Secret Weapons of the Luftwaffe" lets you fly American P-51s, B-17s, and P-47s against the best the Germans had to offer during World War II, including the Me 262 jet and Me 163 Komet rocket plane. Each of dozens of scenarios faithfully reproduces the flying characteristics of the aircraft, including the P-38's tendency to develop engine trouble above 25,000 feet, the Mustang's renowned agility, and the helpless feeling of flying a damaged B-17 while separated from the protective "combat box" and set upon by a horde of Messerschmitts. When the program is used with a joystick, a digital soundboard, and a pair of small speakers, the illusion of aerial combat is surprisingly realistic.

—Douglas Gantenbein is a Seattle-based freelance writer.

CREDITS

Hedge Hopping. Peter F. Girard is a former chief engineering test pilot with Ryan Aeronautical Company in San Diego, California.

Outfield Fly. Hap Rocketto is a private pilot with over 20 years of experience in both the Navy and the Army National Guard and is a science teacher at a vocational-technical high school in Westerly, Rhode Island.

Above the Sky. Doug Stewart lives in Massachusetts. He wrote "The Floating World at Zero G" for the August/September 1991 issue.

The Smokejumpers. Tom Harpole's experiences jumping from airplanes, logging, and wildland firefighting led him into this story. His last article in *Air & Space/Smithsonian*, "Can Russia's Space Program Survive?" appeared in the February/March 1993 issue.

Rendezvous in Space. James E. Oberg reminds us to remind you that the observations and opinions expressed in his article are entirely his own and not attributable to NASA, his employer.

Battle of the Big Shots. Frank Kuznik is a frequent contributor to *Air & Space/Smithsonian*. His last article was "Is Something Out There?" (April/May 1993).

Further reading: *Arms and the Man: Dr. Gerald Bull, Iraq and the Supergun*, William Lowther, Presidio Press, 1991.

The High Sign. Linda Shiner is the senior editor of *Air & Space/Smithsonian*.

At the Point of Singularity. Ann K. Finkbeiner lives in Baltimore, where she writes about cosmology and teaches at Johns Hopkins University.

The Tell-Tale Hoax. Frequent contributor Richard Sassaman lives in Bar Harbor, Maine. He would like to ride in a balloon someday, but not across the Atlantic.

Further reading: *The Eagle Aloft*, Tom D. Crouch, Smithsonian Institution Press, 1983.

CALENDAR

August 7
Community Appreciation Day Airshow. Displays, current and vintage aircraft, aerial demonstrations, bands, food. Langley Air Force Base, VA, (804) 764-2018.

August 12–15
Sentimental Journey to Cub Haven Fly-In. Seminars, displays, flybys, entertainment. William T. Piper Memorial Airport, Lock Haven, PA, (717) 893-4200.

August 15
Eighth Annual Vintage Aircraft Display and Ice Cream Social. Sponsored by Experimental Aircraft Association Chapter 11. Capitol Airport, Brookfield, WI, (414) 962-2428.

August 21 & 22
Airshow. Sponsored by the Prairie Aviation Museum. Bloomington/Normal Airport, Bloomington, IL, (309) 663-7632.

August 28 & 29
Experimental Aircraft Association Chapter 36 Fly-In. Washington County Regional Airport, Hagerstown, MD, (301) 739-0074.

September 4 & 5
"Down Home" Fly-In. Sponsored by Experimental Aircraft Association Chapter 240. Antiques, flybys, flymarket, pancake breakfast, cookout. Rainbow's End Airfield, Salem, NJ, (215) 566-5869.

September 11 & 12
28th Mid-Eastern Regional Fly-In. Workshops, designer forums, pilot seminars, warbirds, classics. Marion Municipal Airport, Marion, OH, (513) 849-9455.

Dubois-Jefferson County Aviation Days Airshow. Clearfield-Jefferson County Airport, Reynoldsville, PA, (412) 846-9922.

September 16–19
National Championship Air Races. Four classes of closed-course pylon air racing. Reno/Stead Airport, Reno, NV, (702) 972-6663.

September 25 & 26
Denver International Airshow. U.S. Thunderbirds, wingwalking, aerobatics, flybys, parachute demonstrations, gliders, displays. Denver International Airport, Denver, CO, (303) 391-5905.

"The Satellite Sky" Update/37

These regular updates to "The Satellite Sky" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

Cosmos 2244
4-28-93 TT

Resurs F-2
5-21-93 PL

Progress M-18
5-22-93 TT

300 to 630 MILES

Cosmos 2242
4-16-93 PL

630 to 1,250 MILES

Cosmos 2245-50
5-11-93 PL

6,200 to 13,700 MILES

GPS-20
5-13-93 CAC

21,750 to 22,370 MILES

Astra-1C
5-11-93 KOU

Deletions

90 to 300 MILES

MAK-2
down 4-1-93

300 to 630 MILES

Cosmos 2122
down 3-28-93

Launched but not in orbit

90 to 300 MILES

Cosmos 2243 CIS photo recon	4-27-93	down 5-6-93
STS-55 U.S. research	4-26-93	down 5-6-93

Inoperative but still in orbit

300 to 630 MILES

Cosmos 2173

21,750 to 22,370 MILES

Ekran 17

DATA: SAUNDERS KRAMER

FORECAST

In the Wings...

Fly Me a River. In Canada's coastal timberlands, fire is a big problem that requires a big solution. Forest Industries Flying Tankers Limited meets the challenge with the world's largest flying boats, the Martin Mars bombers. With 200-foot wingspans and vast cargo holds, the giants can scoop up 60,000 pounds of water and get it to a burning forest fast.

PHIL SCHOFIELD

Project Echo. Before Telstar ushered in the era of the global village in 1962, NASA proved the concept of satellite communications by orbiting Mylar balloons to reflect radio signals. The immense success of the Echo balloons followed some spectacular failures.

Upstart Airlines. In today's economic climate, what kinds of people would try to start a new airline? All kinds.

X-Planes. They were built to be experiments in aeronautics, and some of them, like the X-1 and the X-15, became legends. But the family of X-planes designed for the armed services and the National Advisory Committee for Aeronautics also includes some of the goofiest looking machines ever to fly. In an illustrated supplement, an X-plane gallery will detail the achievements and failures of the 31 aircraft marked "experimental," including the ones that never got off the drawing board.

JOHN HEINLY

A Second Chance

Driving into Florence, South Carolina, from the east, it looks like the region's primary crop is mobile homes. Along both sides of U.S. 76/301, the manufacturers—Accent, Allen, Palmetto, Oakwood, Destiny, Clayton—await buyers. But suddenly, on the left, a field comes into view holding big airplanes instead of double-wides: a B-47 bomber, T-33A Shooting Star, F-86H Sabre, F-104B Starfighter, C-97 Stratofreighter. Some two dozen aircraft and rockets await visitors to the Florence Air & Missile Museum.

The museum's history is long (30 years) but not always distinguished. The original director, having started the collection at Florence Regional Airport to honor Air Force and Air Corps veterans, did little to maintain it. Three disasters, one per decade, didn't help either: in 1969, I-95 was completed, which took away north-south traffic; I-20 did the same for east-west traffic in 1975. And in 1989 hurricane Hugo shut the place down for seven months.

Neighbors began to complain that the museum was becoming an eyesore. Airport commission chairman Jimmy Brown told the press, "The museum used to be an asset. Now it's a liability to this airport." In November 1991 airport commissioners voted to close the place.

Last spring the Air & Missile Development Corporation, a group of Florence businessmen, gained permission to try to improve the museum's image. They began by hiring Al Stein as museum director.

"We know we're not as polished as some other museums," says Stein. "We think of ourselves as a destination for veterans and military personnel. Someone will call and say, 'Hey, I hear you got such-and-such out there. Is that true? I worked on one of those.' Sometimes our visitors flew these exact same airplanes. Three weeks ago the assistant crew chief of that B-47 came by."

B-47s have a special meaning to the locals, ever since March 11, 1958, when a bomber on a training run accidentally dropped a bomb on Mars Bluff, a small community four miles east of the museum. The warhead was not carrying a nuclear device, but the conventional explosives left a crater that was 75 feet wide and 35 feet deep. Fortunately no one was killed, but several houses and a church were destroyed. "The crater's a fishing pond now," says Stein.

Florence Air & Missile Museum, 2204 East Palmetto St., Florence, SC 29506. Phone (803) 665-5118. Open 9 a.m. to 5 p.m. daily except Thanksgiving, Christmas, and New Year's Day. Admission $5.

Inside the long, low exhibit building, artifacts are displayed in no particular order. A Saturn rocket countdown clock stands just inside the entrance, across from a moonrock brought back by Apollo 12. An "Aero Med," with rows of colored buttons and graphs that tracked astronaut electrocardiograms, respiratory rates, temperatures, and suit pressures, sits around the corner from an "Apollo SCS Bench Maintenance Test Table."

"This liquid nitrogen cooler tank was used in launching Saturn 3," one sign says. Another notes cryptically "GAM-72 Quail. Air-launched decoy missile carried by B-52." Not much is labeled, but Stein is happy to explain what he's learned about each artifact.

"Look at the cobalt blue glass on the dials of this 1943 BMW generator," he says, opening the cover. "It provided power for a V-2 rocket and its field communications piece. We used to have the V-2 itself but it was a loan from the Air and Space Museum and they recently donated it to a World War II museum in Arques, France." Stein thinks a minute, then exclaims, "BMW! They make good stuff. I bet Phil could get this up and running in two or three weeks."

Project coordinator and ex-Navy Seabee Phil Calhoun is one of many volunteers Stein has attracted in his quest to make the museum a showpiece. Another is Les Zigler, the last radio maintenance technician on duty at the field when it was the Florence Army Air Base during World War II. Zigler is using his skills as a watchmaker to clean and rebuild gun- and bombsights.

Stein points out a F-84F Thunderstreak donated in 1972 by the Ohio National Guard. "It surprises me to some extent the nostalgia Air Force people have for this equipment," he says. Stein served in the Navy for 10 years, finishing up with three tours in Vietnam. "I mean, I wouldn't try and find my old destroyer escort."

"You're just not old enough," says visitor Ed Caram. An Air Force photographer in the 1960s, Caram now lives in North Carolina. He last came here five or six years ago. "You've got the place nicely done up," he tells Stein.

"I'm mostly just sorting out the mess," Stein says. "But I do want to set up a veterans' display area by the entrance hall. The veterans come here with their families. They want to show them the planes they flew or what they worked on. I've had guys hug the planes. Korean veterans crying over the Sabre out there. Anything here, you can smell it, taste it, feel it, I don't care. By 'feel it,' I mean you can touch these artifacts physically, or they can touch you emotionally."

The rough beginnings of Stein's display include a chemical warfare mask from Desert Storm, donated by members of the 33rd Fighter Squadron at Shaw Air Force Base, a Nazi air warden arm band donated by a visitor from Pennsylvania, and an ammo belt holding 50-caliber bullets with tracers. "That was donated by a local man who doesn't want us to mention his name," Stein says. "I don't know where he got it and I didn't ask."

About 6,000 visitors have come here in the last 12 months, even though the state highway department, upset about the disorder back in 1991, took down most of the road signs directing people to the museum. "This is like *Field of Dreams*," Stein says. "I know they're gonna come."

—Richard Sassaman

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